

ROENTGEN INTERPRETATION

A MANUAL

FOR STUDENTS AND PRACTITIONERS

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PIONEER IN ROENTGENOLOGY

AND

MARTYR TO HUMANITY

PREFACE TO THE FIFTH EDITION.

IN the preparation of the fifth edition of this book the authors have attempted to bring the subject matter up to date, and to present briefly such advances in diagnosis and technique as have appeared since the last publication. It is our purpose, as in the past, to present a brief survey of the field of roentgen-ray diagnosis. Such a survey can do little more than cover the essentials of the subject; more detailed textbooks, monographs and literature may be relied upon to supply further data, if required. The references have been particularly selected with this purpose in view.

Some of the illustrations have been chosen as typical lesions, whereas others present only momentary phases of constantly changing and extremely variable processes. The beginner, therefore, should not attempt to make his diagnosis by a comparison of his own films with those reproduced in the text.

A thorough knowledge of pathology is a fundamental requisite to success in his work. The student should miss no opportunity of correlating the roentgen-ray evidence with the anatomic findings whenever it is possible. Constant collaboration with the other branches of medicine and surgery is equally necessary and profitable.

The authors again wish to acknowledge the privilege of publishing illustrations from the files of the roentgen-ray departments of the following institutions: The Massachusetts General Hospital, Boston; the Hospital for Children; Shriners' Hospital for Crippled Children; University of California and St. Luke's Hospitals, San Francisco.

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ROENTGEN INTERPRETATION.

INTRODUCTION.

It cannot be emphasized too strongly in the beginning: (1) that roentgen images are shadowgraphs; (2) that they are the record of the varying opacities through which a bundle of rays pass; and (3) that they are subject to the possibility of erroneous deductions consequent upon the fact that they are shadows.

Objects are visible only when they differ in density from their surroundings. The outline of the heart is distinct against the air-filled lung surrounding it, whereas the uterus, of similar density, is lost in the shadow of the pelvis.

Furthermore, the roentgenogram is a projection on a flat surface of everything on every plane between the film and the target of the tube. In addition to the patient, this includes opaque objects upon the filters, the clothing of the patient and the envelope of the film. The shadow of a rounded bone with ridges on opposite sides will appear upon the film as a flat image with two dense lines representing the ridges lying side by side. It is therefore essential that the roentgenologist become familiar with the projected appearances of anatomic structures, so that he may be able to visualize from a flat film the relative depth of objects seen upon it. The study of stereoscopic films in this connection is of great value in the development of accurate visualization.

Another source of possible error lies in the fact that divergent rays are employed almost exclusively in roentgenology. Parallel rays, except in the determinations of the size of the heart, are seldom used.

Ordinarily images are produced by a tube relatively close to the film, and the objects in the path of the rays are distorted according to their position with reference to the film. Objects in contact with the film give images of actual size, and are sharply outlined. Objects at a distance from the film appear hazy and proportion-

ately increased in size. When a wide field of illumination is employed, the central rays are practically parallel, but at the margins of the field they strike obliquely, producing a distorted image. This is particularly evident in views of the spine, in which one or two bodies in the center of the film are well outlined, whereas others above and below obscure one another to varying degrees. It is customary, therefore, to limit the rays as much as possible to the central bundle by the use of diaphragms, and to place the area under observation as near as possible to the film. Another advantage to be gained by the use of diaphragms is that the films obtained thereby are brighter. Everything in the path of the rays gives off secondary radiation and scatters the primary beam in the same manner as light is scattered by fog. This secondary and scattered radiation tends to obscure the image produced by the primary rays, therefore, the area of tissues exposed to the rays should be reduced to as small a field as possible, unless a grid diaphragm of some type is employed. This will eliminate scattered radiation and give bright images, but the distortion due to oblique rays is always present toward the edges of the larger films. When small films are used, this divergence of rays is of no great importance, as all the rays striking the film are practically perpendicular to it.

Advantage may be taken of this divergence of rays in some examinations by placing the patient in a position so that the areas to be examined lie along a curve, the center of which is the focal spot of the tube. For example, the thoracic spine is well projected in its entire length with the tube anterior to the patient, whereas in the lumbar spine only one or two bodies can be clearly outlined with the tube in this position. To demonstrate lumbar bodies to the best advantage on one large film, the patient should lie face down upon the film, except, of course, in the case of a patient with a large, thick abdomen. Similarly, better projections of carpal or tarsal bones may be obtained if the dorsum is in contact with the film, and the incident rays are directed to the palmar or plantar surface.

When the Bucky diaphragm is not used, small cones and films should be the rule, except in the extremities when the entire extent of a long bone is desired. In this case no large amount of tissue thickness is involved, and the errors of distortion can be minimized by placing the tube over the point of chief interest.

It is obvious that the part under investigation should be as nearly as possible in contact with the film, *e. g.*, the clavicle should not be taken upon films placed behind the scapula.

A roentgenogram showing only one view is an isolated observation, and is to be relied upon less, perhaps, than a single observation in any other branch of medicine.

In so far as possible, films should be obtained in planes at right angles to each other. In many cases a series of films obtained from various angles will be required to establish a diagnosis. In studies of the skull, the spine and the region of the joints, this should be a routine procedure.

There are several rules which form the basis of successful roentgen interpretation:

(1) Become familiar with the projected appearances of normal structures.

(2) Use routine positions for all examinations as far as possible.

(3) Do not attempt to include everything on one large film. Several small films are preferable.

(4) Do not make a diagnosis before everything possible has been done. Thoroughness is absolutely essential.

(5) Do not express an opinion on poor films.

In order to avoid confusion in the use of the terms "increased" and "diminished density," it should be borne in mind that when they occur in the text they apply to the tissues of the patient.

"Increased density" means the loss of transparency to the rays, with a corresponding light area on the roentgenogram; and "diminished density" means increased radiability, with corresponding darkening of the film.

Many of the illustrations in the text are positives of the original roentgen negatives, therefore, their values are the reverse of those in the roentgenograms.

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CHAPTER I.

CONFUSING SHADOWS AND ARTEFACTS.

THERE are many shadows in films of the normal which may cause errors in interpretation. Their significance is obvious when they have once been recognized, but the beginner is prone to attach undue importance to them, particularly when they occur in regions to which his attention has been directed by the clinical picture. In case of doubt it is always wise to take films of corresponding parts, or to compare them with other films of the same region in other individuals.

Lines Mistaken for Fractures.—The most common error here occurs with the epiphyseal lines, which appear as a definite break in the continuity of the bones. It is therefore essential for the roentgenologist to have a complete knowledge of the time of appearance of the various centers of ossification, the location of epiphyseal lines and the approximate age at which they disappear.

When one bone overlaps another, or the edge of a muscle bundle crosses a bone, there may be a thin, sharply drawn black line which at times resembles a fracture. This appearance is often noticed in the transverse processes of the lumbar vertebrae where the inner margin of the psoas muscle crosses them.

A third possibility of error is furnished by the markings due to bloodvessels, which are particularly evident in the skull, where the course of the middle meningeal artery appears as a tortuous groove behind the coronal suture and is more or less sharply outlined. The venous channels in the diploë of the skull provide another set of dark lines, irregular in their course and indefinite in outline. In the long bones there is ordinarily a definite groove where the nutrient artery enters the shaft, which may be mistaken for a fracture when seen in profile, as, for example, in the phalanges of the hands and feet. It is well, therefore, to be familiar with the anatomy of these vessels.

An accurate knowledge of the location and appearance of the sutures of the skull will prevent their misinterpretation. The lower portion of the lambdoid suture is often mistaken for fracture of the base.

Variations in skeletal development may be mistaken for fractures. They are usually bilateral but not necessarily so.

Divided sesamoid bones are a common example. The internal sesamoid of the great toe is frequently divided transversely into two rounded masses. The patella may develop from several ossification centers which fail to unite. Supernumerary bones are common in the hands and feet and must not be mistaken for chip fractures. Small separate bones are occasionally seen along the upper margin of the acetabulum. Any of the several centers of ossification in the vertebrae may fail to unite and at times they are difficult to distinguish from old fractures. Recent fractures usually have a more clean-cut and sharply defined outline.

The characteristics of a fracture line which are usually sufficient to identify it are: (1) it is a dense black with sharply cut margins; and (2) its course is usually irregular and, particularly in the skull, at variance with that of the bloodvessel markings.

Roughening of the Margins of Bones Mistaken for Periostitis.—Frequently there is a thin plate of bone extending out on the intermuscular septum where bone and fibrous tissue meet, as, for example, between the tibia and fibula, or radius and ulna, which seen in profile is quite suggestive of periosteal proliferation, and one must be careful to differentiate this condition from a true periostitis.

A similar process is prone to occur at the attachment of tendons, such as the tendo Achillis, the triceps, along the margin of the iliac crests, along the linea aspera of the femur and about the external occipital protuberances of the skull. There is very commonly a roughening and slight proliferation along the margins of the phalanges of the hands, which is without significance. The flange behind the intercostal groove on the inferior margin of the ribs posteriorly is often exaggerated and suggests a periostitis. The tibial tubercle may be somewhat widened and its lateral margin projected outside the outer border of the tibia a short distance below the head, and it is frequently mistaken for a localized proliferation of periosteum. There is normally a variable amount of roughening on the inferior margin of the pubes and ischial tuberosities.

A true periostitis appears as a more or less extensive deposit of new bone upon a normal-appearing cortex. This deposit may be laid down in multiple, thin lamellæ, giving it a delicately stratified structure, which is a form frequently seen in lues; or it may be a low, irregular fringe, as seen in some forms of osteomyelitis.

Calcifications.—Calcium deposits cast a dense shadow wherever they occur. They have an extensive distribution in the body outside of the bony structures, particularly in cartilage. Here the

deposit occurs in irregular plaques in and about the surface leaving the center transparent. This is best seen in the costal cartilages which appear in chest, spine, gall-bladder and kidney films. These shadows are without significance and their nature is, as a rule, easily determined.

Calcification also occurs in the same manner in the cartilages of the larynx, and is easily recognizable in lateral views of the neck. In anteroposterior views of this region, however, they are projected upon the lateral masses of the cervical vertebræ and have been mistaken for hypertrophic changes in the spine or calcified vertebral arteries.

Old foci of tuberculosis are common sites of calcification, examples of which are the irregular masses seen in bronchial, cervical and abdominal glands. They are characterized by agglomerations of small masses, which produce typical irregular, mulberry-like shadows. They are usually multiple. Small, rounded, dense masses sometimes occur scattered throughout the spleen and may occur anywhere beneath the peritoneum as the end-result of localized, tuberculous processes. Irregular calcification is often encountered in tuberculous kidneys. Extensive sheets of calcification are sometimes seen in the pleura, in the pericardium, and in the myocardium.

The calcification which occurs in arterial walls as a result of arteriosclerosis is a familiar picture. It may be found in the course of any of the arteries, and is sometimes extensive and striking. The age of the patient must always be taken into consideration in estimating its proper significance. These changes occurring in the internal iliac arteries may be mistaken for stone in the ureter.

Calcification appears in veins in the form of small, rounded, dense masses, so-called phleboliths, which represent small calcified thrombi on the distal side of the valves. They are most common in the pelvis in the region of the ischial spines where they are frequently mistaken for ureteral stones. They may also occur in the superficial veins, particularly in the leg. Rarely calcification similar to that seen in arteriosclerosis may appear in varicose veins.

Extensive calcification may occur in hematomata, and is most commonly seen about the elbow and in the quadriceps extensor. It may develop rather suddenly several weeks after an injury, and present an appearance on the film which may be mistaken for periosteal sarcoma. Whole muscle groups may become calcified in myositis ossificans.

Deposits of calcium may form about foreign bodies, such as silk sutures, the cysts of parasites and very rarely within a dead fetus.

The most common calcified parasite found scattered through the musculature of the body is the cysticereus. It ranges in size from 4 to 8 mm. in length and 1 to 2 mm. in diameter.



FIG. 1.—Calcification in angioma.

Trichina has a similar distribution. The parasites are usually under 1 mm. in length and they do not calcify as frequently.

Dead filaria may calcify to form long, thin strands in the soft tissues.

Calcification is fairly common in tumor masses when the blood supply has been obliterated, as, for example, in uterine fibroids. It is encountered also in other slow-growing, benign tumors of the

connective-tissue group, such as fibromata and lipomata. It occurs in slow-growing, scirrhous carcinomata, in sarcoma of the lung, in some tumors in the pancreas and gall-bladder and in glandular metastasis. Angiomata may contain round, cyst-like masses of varying size, representing calcified thrombi; and endotheliomata may show irregular dense areas, particularly in the skull.



FIG 2.—Calcified cysticercus.

Small, thin plaques often occur in the dura mater and falx cerebri. Deposits are also seen in the pineal, thyroid, testes, ovaries and other glands; and in the subcutaneous tissues of the shins, dense scar tissue, and along tendons and their attachments as a result of previous inflammation or trauma.

Spotty areas of calcification have been seen in the skin and subcutaneous tissues at the finger-tips in patients with Raynaud's disease and scleroderma.

Infarcts of any of the viscera may subsequently calcify. Disturbances in calcium metabolism or local changes in tissue chem-

istry may produce a deposit of calcium salts in the kidneys, cartilages, mucous membranes, stomach, arteries or soft tissues.

Concrements.—Solid calcareous masses, usually the result of chronic infection, are found in the nose, tonsils, salivary ducts, appendix, bile passages, pancreas and genito-urinary tract.

Bodies lying loose in cavities, particularly if they develop from an organic nucleus, give annular shadows.

Teeth are sometimes recognizable in dermoid cysts.



FIG. 3.—Intramuscular iodine injection. The shadow of the metallic deposit can be seen scattered over that of the pelvic bones.

Areas of Increased Density in Spongy Bone.—Small round areas of condensation are sometimes seen in cancellous bone. There is no disturbance in the normal structure of the bone about them,

and their significance has been a matter of considerable speculation. They may represent old healed areas of infection, a localized disturbance in the growth of the bone or the presence of small islands of cartilage which have become calcified. They have no clinical importance.

The transverse dense lines, often multiple, which occur along the medullary canal toward the ends of the long bones, are the result of disturbances in calcium metabolism which occurred at the time when the epiphyseal line was at that level; they may be likened to the growth rings in the trunk of a tree.

Warts and Fibromata on the Skin.—Any area of skin which presses heavily on the cassette will be recorded as a spot of increased density, common examples of which are outlines of the buttocks of a thin individual in a film of the entire pelvis, the breasts of women in anteroposterior films of the chest, or the ears in lateral skull films. In the same way warts and fibromata appear as rounded areas of increased density. Over the kidney or gall-bladder regions they may strongly suggest calculi. A characteristic which may help to identify them is that they have extremely sharp margins because of the fact that they are in contact with the film. The presence of fibromata should always be noted in the patient's record.

Metallic Salts.—Bismuth or barium salts which have remained in sinuses after injection, or in portions of the gastro-intestinal tract following routine examinations are occasionally seen.

Following the intramuscular injection of bismuth or mercury, dense shadows appear in the soft tissues and may persist indefinitely. Surface applications of iodine or mercury or other metallic ointments may cause confusing shadows.

Iodine in any form casts a particularly dense shadow, hence its use in an oil compound to outline bronchial ramifications, subarachnoid space, old sinuses or other body cavity. Various solutions of iodids are employed in pycnography, and in the demonstration of the gall-bladder. Bromids are similarly useful, but less opaque. Residues of iodized oil may be found in the spinal canal, thorax and soft tissues long after injections have been made.

Gas.—Air or gas in the soft tissues gives a characteristic picture. In subcutaneous emphysema, the patient at first sight appears to be in a plaster cast, so striking are the alternate light and dark areas in the affected region. Accumulations of gas, particularly in the colon where it overlies the spine, the wings of the ilia or sacrum, are sometimes mistaken for areas of rarefaction in the bone. Careful

inspection will reveal the presence of normal bone structure in the doubtful area, or the patient may be reexamined.

Gas appears in the soft tissues early in the development of gas gangrene. It infiltrates and expands individual muscle bundles and must be differentiated from pockets of air which may be seen in the soft tissues following surgical operations or punctured wounds,



FIG. 4.—Gas gangrene following amputation of the leg. Note the sharply defined bright areas in the soft tissues.

when air is introduced between the muscles. This differentiation is not easy at times.

Clothing, Dressings and Jewelry.—As a general rule, all clothing and dressings should be removed from the part to be examined, but this is not always possible. The examiner should therefore be familiar with the shadows cast by these objects. Colored silks, especially the cheaper varieties, give a general haziness or dense

lines where folds or wrinkles occur. Sheets and draping, if not properly rinsed, may also produce similar shadows. Metallic objects, such as earrings or buttons, cause little difficulty if close to the film, but if they lie a considerable distance from it so that their shadows are blurred, they may be misinterpreted. Earrings have been mistaken for tooth roots and buttons for gall stones.

Defective Films.—Films may show irregular light or dark areas as a result of defects of manufacture, or fogging by light, radium or roentgen-rays. One particularly troublesome defect is the occurrence of localized crescentic light spots produced by buckling or crinkling of the film before it is exposed. Spots which tend to be repeated on successive films are usually due to a defect in intensifying screens, or foreign material within the cassette or upon the filter. Irregular patterns of increased or diminished density occasionally result from uneven immersion of the sensitive surface in the developer. They are very sharply marked and have long curved outlines. Finger-marks appear on films as light or dark spots, depending upon the substance present on the finger at the time of impression. Their presence is always an indication of faulty dark-room technic.

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CHAPTER II.

ANATOMICAL VARIATIONS AND DEVELOPMENT

ANATOMICAL variations in bone structure may occur anywhere in the skeleton, and are of considerable importance aside from their interest as curiosities, for they are commonly points of lowered resistance. A strain or injury which would be without effect on a normally constructed individual may give rise to severe and stubborn symptoms when such anomalies are present. This is particularly true of variations in the spine, which will be considered in a later chapter. Anomalies are frequently multiple, *e. g.*, spina bifida and rib fusions

Skull.—The skull may show partial absence of bones or variation in the width of sutures, which remain into adult life. The frontal bone develops from two centers, and a suture line may persist in the mid-line between them. The occipital region may show multiple abnormal sutures. Thin areas appearing as holes are occasionally seen in the frontal and parietal regions and along the sagittal suture. The sinuses and mastoids are subject to wide variation, from complete absence to enormous size. Cases have been observed in which the mastoids communicated with the sphenoid sinus anteriorly and with each other posteriorly. Partial or complete absence of the cranial vault, resulting in ancephalic monsters, has been demonstrated before birth.

Ribs.—Extra ribs may appear in the lower cervical or upper lumbar regions, or they may be attached to extra bodies. Cervical ribs may be of sufficient length to articulate with the sternum, or become attached to the first rib. They are usually longer than they appear on the film, due to foreshortening of their shadows. On the other hand, one or more ribs may be absent, or partially so, or adjacent ribs may be fused. A mild form of this latter condition is frequently seen near the sternal end, where a rib may flare considerably before its attachment to the costal cartilage, and this enlargement may or may not be perforated.

Scapulæ.—These bones vary considerably in thickness, and holes may occur in the thin regions. Unusually prominent grooves may

simulate fractures. There is a congenital elevation of the scapula (Sprengel's deformity), in which a partially developed scapula is found high up toward the neck. The lower margin of the glenoid may fail to develop or the articular surface of the glenoid may be

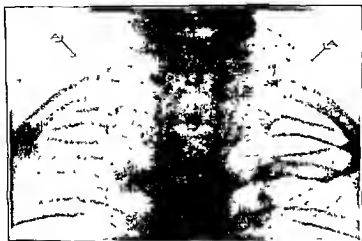


FIG. 5—Double cervical ribs at A



FIG. 6—Congenital elevation of the scapulae.

convex, with a corresponding depression in the head of the humerus. In cases of obstetrical paralysis, there may be an imperfect development of the scapula and head of the humerus.

Variations of the Carpus.—Perhaps the most important anomaly here is the divided scaphoid, which is to be differentiated from a

fracture of the scaphoid. The margins of the halves are more rounded and smooth, and the space separating them is not quite so black as in the case of fracture. The semilunar bone and the sesamoid of the thumb may be similarly divided. Proximal epiphyses are often seen upon the second metacarpal, less commonly upon the fifth. Various accessory bones are shown in Fig. 7, of which the most common is the styloid. This bone develops from a separate center of ossification and is seen lying between the trapezoid and magnum, opposite the third metacarpal.

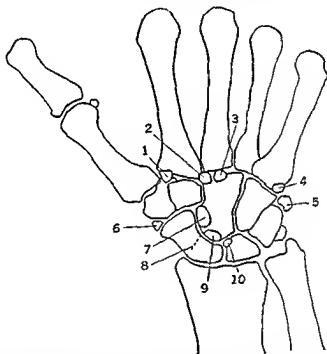


FIG. 7.—Common variations in the carpus. (These accessory bones may exist separately or be united to any of the adjacent bones.) 1, pretrapezium, 2, styloid, 3, subcapitulum, 4, os vesalianum, 5, ulnare externum, 6, radiale externum, 7, centrale; 8, divided scaphoid, 9, hypolunatum, 10, epilunatum.

. **Phalanges.**—The phalanges are usually involved in generalized anomalies of development, as in acromegaly, where the phalanges are strong and heavy, with a coarse cancellous structure, and the terminal phalanges tufted at the tip.

In cranio-cleido dysostosis the distal phalanges are short and conical, the middle phalanges short, and the proximal row expanded

at the base. The metacarpals are expanded at both ends, with narrow, dense shafts. These changes occur in both hands and feet. There are associated defects in the skull, clavicles and pelvis.

Arachnodaactylia presents strikingly long slender bones, associated with deformities of the skull and thorax and hypotonicity of the muscles. The forehead is prominent, the eyes widely spaced, the trunk is short, the limbs are long and slender with a disproportionate elongation of the fingers and toes.

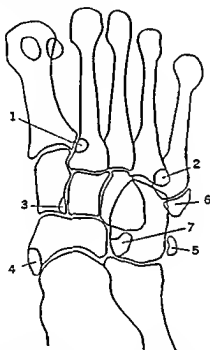


FIG 8.—Common variations of the tarsus. (Anterior-posterior view.) 1, 2, intermetatarsal; 3, intercuneiform; 4, tibiale externum; 5, peroneum; 6, os vesalianum; 7, secondary cuboid.

Variations of the Tarsus.—The astragalus bears a backward prolongation of variable length which often exists as a separate bone, the trigonum, and when present it must be differentiated from a fracture of a long process. The next in order of importance is the tibiale externum, a small detached bone which sometimes occurs at the posterior end of the scaphoid on the inner side of the foot.

The small separate center of ossification on the outer side of the

posterior end of the fifth metatarsal may persist into adult life as a small bone called the *vesalianum*.

Divided sesamoids in the tendons of the *flexor brevis hallucis* beneath the head of the first metatarsal are fairly common. They must be carefully differentiated from fracture of single sesamoids, which are extremely rare. Other variations are outlined in Fig. 8.

The subject of variations in the hands and feet is exhaustively treated by Dwight.

Other Bony Variations.—In every roentgenologic practice, one may encounter cases of partial or complete absence of long bones, particularly the fibula, radius and phalanges. On the other hand, supernumerary bones, usually extra fingers or toes, may also be seen. Development may proceed from several centers which may fail to unite later. The patella is an example. It may show one or more triangular or crescentic masses about its margins, which may be differentiated from fractures by the fact that their edges are smooth and that the condition is usually bilateral. Fusion of bones may occur. This is most frequently found between metacarpals, phalanges or radius and ulna. Adjacent carpal and tarsal bones may be united, and there is an hereditary anomaly in which the first and second phalanges of one or more digits may coalesce with obliteration of the interphalangeal joint. Short terminal phalanges are seen on the thumbs, fingers and toes, and sometimes single, short, small metatarsals or metacarpals occur in cases of *myositis ossificans*. Mongolian idiots often have short middle phalanges on the fifth fingers and relatively short ulnae. Atavistic variations may occur as for example, the hooked supracondylar process occasionally found on the inner margin of the humerus above the elbow, or a crescentic sesamoid bone, the *patella cubiti*, found close above the tip of the olecranon.



FIG. 9 — Supernumerary thumb

Chinese women, through years of binding of the feet, develop a markedly accentuated plantar arch.

Ossification.—Variability is also evident in the time of appearance of centers of ossification. In girls they usually appear earlier than in boys.

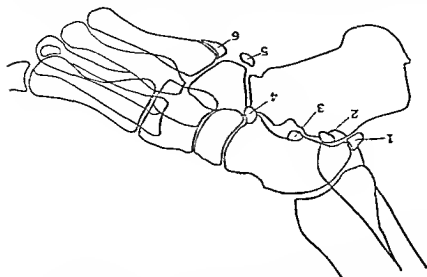


FIG. 10.—Common variations in the tarsus (lateral view). 1, trigonum; 2, accessory talus, 3, os sustentaculum, 4, tibiale externum, 5, peroneum; 6, os vesalianum.

TABLE OF APPEARANCE OF CENTERS OF OSSIFICATION IN THE FETUS.

<i>Head.</i>		
Mandible		7th week
Occipital bone—squamous portion		8th "
lateral and basilar		9th to 10th "
Superior maxilla		5th "
Temporal bone—petrous, mastoid and zygoma		9th "
Sphenoid—inner lamella of pterygoid process		9th "
great wings		10th "
lesser wings		13th "
anterior body		13th to 14th "
Nasal bone		10th "
Frontal bone		9th to 10th "
Bony labyrinth		17th to 20th "
First dentition—rudiments		17th to 25th "
Hyoid bone—greater cornua		29th to 32d "
<i>Shoulder Girdle.</i>		
Clavicle—diaphysis		7th week
Scapula		8th to 9th "
<i>Upper Extremity</i>		
Humerus—diaphysis		8th week
Radius—diaphysis		8th "
Ulna—diaphysis		8th "
Phalanges—terminal		9th "
basal 2d and 3d		9th "
basal 4th and 1st		10th "
basal 5th		11th to 12th "
middle 3d, 4th, 2d		12th "
middle 5th		13th to 16th "
Metacarpals—2d and 3d		9th "
4th 5th, 1st		10th to 12th "

Vertebrae.

Archae—all cervical and upper 1st and 2d dorsal	9th week
all dorsal and 1st or 2d lumbar	10th "
lower lumbar	15th "
sacral	16th to 25th "
Bodies from 2d dorsal to last lumbar	10th "
from lower cervical to upper sacral	11th "
from upper cervical to lower sacral	12th "
5th sacral	13th to 28th "
1st coccygeal	37th to 40th "
odontoid process of axis	17th to 20th "
Costal processes—6th and 7th cervical	21st to 33d "
5th cervical	33d to 36th "
4th, 3d, 2d cervical	37th to 40th "
Transverse processes—cervical and dorsal	21st to 24th "
lumbar	25th to 28th "

Ribs and Sternum

Ribs—5th, 6th 7th	8th to 9th week
2d, 3d, 4th, 8th, 9th, 10th, 11th	9th "
1st	10th "
12th (very irregular)	10th "

Sternum

Sternum	21st to 30th week
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Pelvic Girdle

Ilium	9th week
Ischium—descending ramus	16th to 18th "
Os pubis—horizontal ramus	21st to 28th "

Lower Extremity.

Femur—diaphysis	7th to 9th week
distal diaphysis	35th to 40th "
Tibia—diaphysis	8th to 9th "
proximal epiphysis	40th "
Fibula	9th "
Os calcis	14th to 25th "
Astragalus	24th to 32d "
Cuboid	40th "
Metatarsal—2d and 3d	9th "
4th, 5th and 1st	10th to 12th "
Phalanges—terminal 1st	9th "
terminal 2d, 3d, 4th	10th to 12th "
terminal 5th	13th to 14th "
nasal 1st, 2d, 3d, 4th, 5th	13th to 14th "
middle 2d	20th to 25th "
middle 3d	21st to 26th "
middle 4th	29th to 32d "
middle 5th	33d to 36th "

The following tables give a working average of the time of appearance of ossification centers after birth:

	Time of Appearance Years	Time of Fusion Years
Scapula—coracoid	1	16-18
upper glenoid and base of coracoid	10	15
acromion (two centers)	15	20
vertebral border	18	22

	Time of Appearance Years.	Time of Fusion. Years.
Ribs—epiphyses for head and tubercle	15	23
Clavicle—small epiphysis of the sternal end	22	25
Humerus—head	1	18
greater tuberosity	3	18
lesser tuberosity	4	18
(all fuse at six years and join the shaft at eighteen years)		
capitellum	1	17
internal epicondyle	5	18
trochlea	10	17
external epicondyle	12	17
(The capitellum, trochlea and external epicon- dyle join as a mass at fifteen and the internal epicondyle at eighteen years)		
Radius—head	6	18
lower epiphysis	2	20
Ulna—olecranon	8-10	17
Lower epiphysis	6	20
Carpus—(in the order of appearance):		
magnum	1	
uneiform	1 to 1½	
cuneiform	2 to 3	
semilunar	4 to 5	
trapezium	5	
scaphoid	5 to 6	
trapezoid	6 to 8	
pisiform	10 to 12	
Metacarpals—epiphyses	3	18
Phalanges—epiphyses	3	18
Pelvis—(pubis and ischium unite at eight years, the acetabulum closes at sixteen years):		
epiphyses for	0	0
crest of ilium	15	23
ischial tuberosity		
anterior inferior iliac spine		
tubercle of pubis		
Femur—head	1	18
greater trochanter	4	18
lesser trochanter	11	17
lower epiphysis	birth	20
Patella	2 to 3	24
Fibula—upper epiphysis	4	24
lower epiphysis	2	18
Tibia—upper epiphysis	birth	22
lower epiphysis	2	18
Tarsus—(in order of appearance):		
calcus	birth	
tuberosity of calcus	8	
talus	birth	
navicular	birth	
external cuneiform	1	
internal cuneiform	3	
middle cuneiform	3	
scaphoid	4	
Metatarsals—epiphyses	3 to 8	18
Phalanges—epiphyses	4 to 7	18
Sesamoids of flexor brevis hallucis	5	

Vertebrae—Ossification is from three primary centers, one for the body and one for each lateral mass. The nucleus for the body may be divided. The laminae unite during the first year. Five secondary centers are described in the anatomies—namely, thin plates on the upper and lower surfaces of the body and the tips of the mammillary tubercle, transverse and spinous processes—appear at the age of twelve to fifteen years and unite at twenty-five. The fifth lumbar vertebra is an exception in that it ossifies from five centers, one for the body, one on each side from which are developed the superior articular process, pedicle and transverse process, and one on each side which subsequently form the inferior articular process, lamina and spinous process.

These figures should not be applied arbitrarily. A child, aged five years, may vary six months either way from the figures given. At ten years at least one year's variation should be allowed and at fifteen years a two year allowance should be made. It must be remembered that some individuals do not show the same stage of development throughout all the epiphyses. In general girls over ten years of age show a bone development about one year in advance of boys of the same age.

APPEARANCE AND UNION OF BONE CENTERS. THESE TABLES HAVE BEEN REVISED FROM THOSE OF ENGELBACH AND McMAHON, CAMP AND CILLEY, AND P. C. HODGES.

Years

- 1 Coracoid process scapula
Head of humerus (six to seven months).
Capitate and hamate.
Head of femur.
Upper epiphysis tibia (birth).
Third cuneiform.
- 2 Greater tubercle humerus.
Capitellum, humerus.
Lower epiphysis radius.
Patella (two to three years).
Lower epiphysis tibia.
Lower epiphysis fibula.
First and second cuneiforms (two to four years).
- 3 Os triangularis.
Heads of metacarpals.
Heads of phalanges, hands.
Heads of metatarsals (three to seven years).
- 4 Lunate.
Greater trochanter femur.
Upper epiphysis fibula (three to four years).
Navicular (tarsal).
- 5 to 6 Union of head and tubercles of humerus.
Medial epicondyle humerus.
Upper epiphysis radius.
Greater multangular.
Lesser multangular (six to eight years).
Navicular (carpal) (five to six years).
- 7 Lower epiphysis ulna.
Union of ischium and pubis.
Epiphysis os calcis (seven to nine years).
- 9 Platform (nine to eleven years).
- 10 Olecranon, ulna.
Trochlea, humerus.
- 11 Lateral epicondyle humerus (eleven to twelve years).

- Years**
- 13 Lesser trochanter femur.
Olecranon—Female.
- 14 Union of heads of metacarpals (fourteen to fifteen years).
Epiphysis on calcis—Female.
- 15 Acromion
Inferior angle scapula
Union of centers of scapula (fifteen to eighteen years).
Sternal end clavicle (fifteen to seventeen years).
Union of heads of phalanges, hand
Appearance of secondary centers on coxae
 (a) Crest of ilium (fifteen to eighteen years).
 (b) Acetabulum (fifteen to sixteen years).
Union of primary centers on coxae
External condyle humerus—Female.
Head of radius—Female.
Trochanters—Female.
Head of femur—Female
Olecranon—Male.
- 16 Union of
 Distal extremity humerus.
 Olecranon, ulna
 Upper epiphysis radius
 Heads of metatarsals
 Heads of phalanges, feet.
 Epiphysis of phalanges and metacarpals—Female.
 Epiphysis of phalanges and metatarsals—Female.
 Epiphysis on calcis—Male.
- 17 Union of
 Lower epiphysis radius.
 Lesser trochanter femur.
 Distal epiphysis of the tibia and fibula—Female.
 External condyle humerus—Male.
 Head of radius—Male.
 Trochanters—Male.
 Head of femur—Male.
- 18 Union of
 Head of humerus
 Greater trochanter femur
 Lower epiphysis tibia
 Distal epiphysis of radius and ulna—Female.
 Greater tuberosity of humerus—Female.
 Distal epiphysis of femur—Female
 Proximal epiphysis of the tibia and fibula—Female
 Epiphysis of phalanges and metacarpals—Male.
 Epiphysis of phalanges and metatarsals—Male.
- 18 to 20 Union of
 Lower epiphysis ulna.
 Secondary centers on coxae (twenty to twenty-five years)
 Lower epiphysis femur.
 Upper epiphysis tibia.
 Lower epiphysis fibula
 Upper epiphysis fibula.
 Distal epiphysis of tibia and fibula—Male.
 Distal epiphysis of radius and ulna—Male
 Head of humerus—Male.
 Greater tuberosity of humerus—Male.
 Distal epiphysis of femur—Male
 Proximal epiphysis of tibia and fibula—Male.
- 22 to 25 Union of sternal end clavicle
 Between the ages of five and twelve girls seem to run about one
 year ahead of the boys; after fourteen about two years ahead.

AREAS TO BE TAKEN FOR BONE-AGE DETERMINATIONS.

Years	
1 to 5	(1) Full figure, divided on two films (2) Hands and feet, taken separately (2) Lateral knee for patella
6	(1) Carpals and tarsals. (2) Shoulder. (3) Pelvis
7	(1) Pelvis. (2) Carpals
8	(1) Carpals (2) Lateral foot
9	(1) Carpals (2) Lateral foot.
10	(1) Elbow (lateral, anteroposterior). (2) Lateral foot. (5) Hand (anteroposterior)
11	Films listed under ages ten and twelve years
12	(1) Elbow (lateral; anteroposterior). (2) Carpals.
13	(1) Hip, with half pelvis. (2) Anteroposterior elbow. (3) Anteroposterior hand
14	Films listed under ages thirteen and fifteen years.
15	(1) Clavicle. (2) Scapula. (3) Pelvis (half). (4) Lateral foot. (5) Hand. (6) Lateral elbow.
16	Elbow (lateral anteroposterior)
17	Pelvis.
18	(1) Carpals. (2) Tarsals (3) Shoulder. (4) Pelvis, with hip-joint. (5) Ankle (anteroposterior).
19	Films listed under ages eighteen and twenty years.
20	(1) Carpals, with wrist. (2) Knees (anteroposterior). (3) Ankle (anteroposterior).
25	(1) Clavicle. (2) Scapula. (3) Pelvis. (4) Knee.

It is well to bear in mind: (1) that epiphyses which appear last are the first to unite, and that the nutrient foramen is directed toward them; (2) that ossification begins earliest in the epiphyses bearing the largest relative proportion to the shaft (except the fibula), and (3) that when an epiphysis ossifies from several centers, they fuse together before uniting with the shaft.

Variations in the normal process of the union of epiphyses are of great importance as a factor in the production of deformities. For example, failure of development of a center in the lateral masses of the fifth lumbar may result in scoliosis. Abnormal fusing of the lower epiphysis of the radius produces the malformation known as Madelung's deformity, in which the plane of the radiocarpal articulation is rotated inward and forward with a relative elongation of the ulna. Deformities due to irregularities in development have been noted in children after smallpox.

Delayed union may accompany retarded mental or physical development, of which a common example is seen in cretinism. It also occurs as a result of infection or injury.

The exact rôle of the various endocrine disorders in affecting epiphyseal centers has yet to be worked out, but it is interesting to note that there is marked delay in the appearance of the various centers and closure of epiphyseal lines in hypothyroidism, and in cases of gonad and anterior pituitary deficiency. The opposite condition of advanced development and early union of epiphyses occurs in patients with overactivity of the pituitary and thyroid.

Variations occur in the normal calcification of epiphyses. They may ossify from several nuclei, or show a central nucleus and a peripheral shell with a clear zone between as a result of healed rickets.

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CHAPTER III.

FRACTURES AND DISLOCATIONS.

FRACTURES.

It is important for the roentgenologist to have a thorough knowledge of roentgen anatomy, and of the surgical pathology of wound and fracture repair. Gross fractures are, of course, obvious, but in a doubtful case the diagnosis may depend entirely upon the breadth of his anatomic and surgical experience. He should remember that the more accurately a fracture is reduced the sooner will function be restored and the smaller the callus which will result. Calcification begins in callus in from one to four weeks, and is usually complete in six. At first callus may show very little evidence of lime deposit when there is no displacement of fragments, but an extensive comminution or a malposition of fragments should be accompanied by a large, thoroughly calcified callus.

It is sometimes advisable to have oblique views with the incident rays directed along the plane of the fracture, to decide whether or not bony union is developing. Oblique views are also necessary at times to separate the radius and ulna or tibia and fibula.

The prognosis of fractures involving joints should always be guarded because of the fact that there is no means of estimating from the roentgen examination how much damage has occurred to the soft tissues, or what effect their repair will have on function. The possibility of organization and calcification in extensive hematomata should be remembered. When the fracture involves a joint, the fact should be mentioned in the report.

The question of union is often a difficult matter to decide from roentgen evidence alone. One cannot determine from a film showing a fracture without evidence of bony union whether there are soft tissues between the fragments which will interfere with repair, whether an uncalcified callus is present, or whether or not there is firm fibrous union. It should be remembered that callus formation in compound fractures is apt to be slow and irregular. Callus is never seen within joint capsules, as in the neck of the femur. Callus is not seen following fractures of the vertebral bodies, skull or ilia.

Non-union is prone to occur when the site of fracture involves a nutrient artery, or when the patient is syphilitic or asthenic.

Usually one cannot distinguish the presence or absence of callus through a plaster cast. Bony union cannot be said to be complete until trabeculae have been demonstrated across the fracture line.

In the reduction of fractures, normal weight-bearing lines should be restored as far as possible, and every attempt should be made to replace articular surfaces in their normal planes with reference to



FIG. 11.—Fracture of the skull in a child. Compare the fracture line with the suture line seen in front of it. A, fracture, B, suture.

the shaft. In doubtful cases, comparison films of a symmetrical part may help to decide whether or not a reduction is satisfactory.

After operation callus formation is apt to be delayed and where plates have been applied callus usually forms best on the sides away from the plate. In the course of time there is a certain amount of bone absorption about plates and screws, without the presence of infection.

Fracture lines will usually become obliterated in from three to

six months, and, if reposition of the fragments has been accurate, all evidence of the injury may have disappeared in that time. The shadows of linear fractures in the skull, however, may persist for several years after the injury. In any fracture, when reduction has



FIG. 12.—Depressed fracture in frontal region. Note the overlapping fragments indicated by the arrow, and the curved fracture line at *A*. *B* indicates the frontoparietal suture line

been poor or the callus formation extensive, evidence of the deformity may persist for life.

The roentgenogram will often furnish evidence of value to the surgeon aside from the position of the fragments, such as indica-

tions of a pathologic process in the bone, or of the presence of foreign bodies within the wound, and, occasionally, the early appearance of gas in the soft tissues as a result of infection with Welch's bacillus.

Skull.—The skull is subject to linear fractures which appear on the film, as thin, black lines with sharp, ragged edges. They may run in any direction. They are to be differentiated from suture lines, diploic veins and bloodvessel grooves, all of which have fairly definite courses, smooth margins and are lighter in color. Fracture

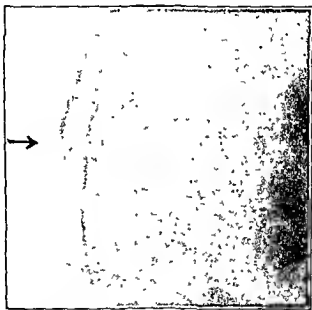


FIG. 13.—Tangential view of fracture in Fig. 12, showing amount of depression present, indicated by the arrow.

lines may open up sutures or follow bloodvessel markings, but they can usually be traced beyond the course of these normal lines.

Comminuted and stellate fractures are generally obvious. A *depressed fracture often appears as a white line because of overlapping of the margins of the break*, therefore whenever possible profile views should be obtained.

Fractures of either the inner or the outer table appear as thin black lines or areas of slight irregularity in the density and structure of the bone. Fractures limited to the base are frequently overlooked, therefore, as a routine procedure, films showing a vertical projec-

tion of the base should be obtained, in addition to anteroposterior, posterior-anterior and lateral views. It is poor judgment to subject a patient with an acute skull fracture to the manipulation necessary for an adequate roentgen examination. The procedure is better carried out after the patient has recovered from initial hemorrhage and shock. This does not preclude the taking of preliminary films in routine lateral and anteroposterior position, with very little disturbance of the patient, in order to determine the presence of gross injuries, but such an examination should not be considered final.

Cranial aërocele may develop following fracture through the sinuses, especially the frontal sinus. It is produced by the increased air pressure within the nasal cavity when the patient sneezes or blows the nose. At this time air and bacteria may be forced through the fracture into the cranial cavity. The pocket containing the air will appear on the film as an area of markedly diminished density, usually in the frontal region.

Vertebræ.—Fracture lines are rarely seen in the bodies of vertebræ. Abnormality in outline or in relations of neighboring vertebræ is the usual finding. This subject is discussed in Chapter VI.

Pelvis.—The examination of this region should consist of a set of stereoscopic films large enough to include the entire pelvis and both hip-joints. The routine position is to have the patient supine, with the film behind and tube in front. In many cases, it is desirable to supplement this with postero-anterior and lateral views. The films should be of sufficiently good quality to show bone detail, and should be free from blurring due to motion.

Pelvic fractures are usually due to violent injuries. They are frequently multiple and often cause considerable deformity. The regions about the sacro-iliac joints and the symphysis pubis are most commonly involved. Typical injuries are fracture or dislocation of the pubis associated with separation of a sacro-iliac joint or fracture of the sacrum or ilium near it. Persons struck by automobiles often show fractures in the pubic region. The femoral head may be driven into the pelvis, carrying the inner wall of the acetabulum before it.

Fractures of the ilium appear as sharply defined lines of diminished density and may be stellate.

Gas in the colon or rectum may simulate or obscure a fracture. These shadows are not constant and can be ruled out by repeated examinations. Bloodvessel grooves in the ilium may also be a

source of error. Their situation, branching character and bilateral occurrence should identify them. The epiphyses of the pelvis are among the last to unite, remaining open until twenty to twenty-five year of age. This fact should be kept in mind in interpreting films of young patients.

Fractures of the pelvis, like those of other flat bones, heal with little or no callus formation and, except when the pelvis is deformed, leave no evidence upon the roentgenogram.

Ribs.—Fractures of the ribs are usually obvious, but may be overlooked in the overlapping axillary shadows. Slight rotation of the patient may bring the injured area into clear view. Views with films both anterior and posterior to the patient should be a routine procedure in all rib injuries. Fracture of the costal cartilage may occur and give no evidence on the roentgenogram unless the cartilage is calcified. Cartilages which are partially calcified show breaks running obliquely or irregularly through them where calcification has not occurred. These should not be mistaken for fractures.



FIG. 14.—Fracture of the scaphoid.

Carpus.—The bones usually involved, in the order of frequency, are the scaphoid, cuneiform and magnum. These fractures are often associated with those of the radius and ulna, and should not be over-

looked by exclusive attention to the latter. In case of doubt, it is advisable to secure films of both wrists in symmetrical position for comparison. It is necessary to have anteroposterior, postero-anterior and oblique films of the wrist to demonstrate some fractures of the scaphoid, as the injury may show on only one film of the three. If there is any question about the diagnosis, a semi-lateral should be taken, with the hand resting on the ulnar side.



FIG 15—Colles' fracture.

Colles' Fracture.—Films for the study of this injury should represent accurate anteroposterior and lateral views at the level of the lesion, otherwise erroneous conclusions regarding the amount of deformity may be drawn. After the arm has been placed in splints or plaster, it may be necessary to employ fluoroscopy to determine the proper position for a correct view.

The usual deformity in this common injury is a compression of the posterior margin of the radius, which results in a backward tilting of the articular surface as seen in the lateral view. After reduction, the former relations of the styloid processes of the radius and ulna

should be restored, and the plane of the articular surfaces brought back as closely as possible to the normal position.

Old fractures are distinguished from recent ones by the presence of rarefaction and the absence of a distinct fracture line.



FIG. 16 —Colles' fracture—lateral view. The shadow of the ulna overlaps that of the radius, and conceals the deformity in the radius

Elbow.—An anteroposterior and lateral view are usually sufficient. In the former, the arm should be completely extended; in the latter, flexed to a right angle. Fractures in this region frequently involve the joint. The roentgenographic interpretation should include a statement as to the presence or absence of joint involvement, as this may influence the treatment. Errors in interpretation are most often due to the presence of epiphyseal lines. For this reason, similar films of the opposite arm are desirable.

Fractures here in the order of frequency are supracondylar fractures of the humerus, fractures of olecranon, head of radius and coronoid process. The two latter injuries may occur without a great deal of displacement, and may be overlooked unless they are carefully searched for on films in several planes. Fracture of the ulna is sometimes accompanied by an unrecognized dislocation of

the head of the radius, the elbow should always be included when a fracture of the ulna is being radiographed.

Shoulder.—The best view of the head of the humerus is obtained with the tube centered above and to the inner side of the joint in order to displace the head of the humerus downward and outward from beneath the acromion. This is also the best position to bring out the region of the subdeltoid bursa. Films should be made both with the hand lying palm up and palm down, thus giving two projections of the head of the humerus at right angles to each other. To show the acromion and neck of the scapula, the tube should be centered considerably below the joint.

The epiphyseal lines here, as in the elbow-joint, make interpretation difficult, and films of the opposite shoulder should be taken for comparison. It may be noted that the epiphysis for the outer end of the acromion process does not unite until the age of twenty (see Fig. 17). Calcification in the subacromial or subdeltoid bursa may simulate a fracture of the greater tuberosity. The shadow of calcification is, however, more dense and irregular than that of bone, and it does not have a trabeculated structure.

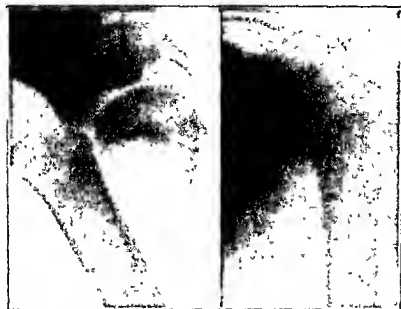
Fractures of the anatomical and surgical necks are usually the result of falls, and they may or may not be impacted. Stereoscopic observation of this region, or a vertical view, is always recommended for the recognition of the true relation of the fragments.

Fractures of the scapula are often overlooked on single films. Films from different angles including a tangential view of the body, and stereoscopic examination will minimize this error.

Tarsus.—Fractures of the os calcis are the most frequent. They produce more or less disturbance in the normal structure consequent upon crushing of the spongy bone and deformity of outline. The line of fracture is seldom seen in later views. The examination for suspected injuries to the os calcis should always include a survey of the posterior halves of both calcis made with the film behind the ankle, the patient lying on his back and the incident ray entering obliquely well down on the sole of the foot. If the patient is able to stand, the film is placed beneath the heel and the tube centered behind the knees. The best view of all the tarsal bones is secured with a film in contact with the dorsum of the foot, the incident rays entering through the sole from the inner side.

Fracture of the astragalus and cuboid are next to those of the calcis in frequency. The posterior extension of the astragalus occasionally occurs as a separate bone called the trigonum (Fig. 10). As

a rule, this condition is bilateral. Whenever a fracture in this region is suspected, films of the other ankle should be taken. Another anatomic variation of the foot which may lead to an error in diagnosis is the presence of a separate ossification center at the base of the fifth metatarsal. This is also usually bilateral.



Vertical projection

Anteroposterior view.

116, 17.—Fracture of the anatomical neck of the humerus along the epiphyseal line. Note that the anteroposterior view does not indicate the amount of deformity present. Epiphysis for the tip of the acromion at "A" should not be mistaken for a fracture.

Pott's Fracture.—In any fracture of the tibia, it is essential that the fibula be explored throughout its extent in order to avoid missing breaks which occur at a different level from that of the tibial injury. The essentials in reduction of a Pott's fracture are that the weight-bearing line and the joint margins be restored accurately, and that the foot be slightly inverted.

Knee.—With good films taken in the anteroposterior and lateral positions, it is usually possible to visualize the line of fracture, and to determine whether or not it involves the joint. Cartilage is not of sufficient density to be distinguished from soft tissue, and injuries involving this structure, such as a displaced semilunar cartilage, or separation of articular cartilage from the condyles are not demon-

strable except in those cases where a small fragment of bone has accompanied the displaced cartilage, or cases of long duration where calcification has occurred in the cartilage.

Fractures of the patella may be either transverse, with wide separation of the fragments, longitudinal, or stellate. Shelving fractures of the upper and lower margins may result from division of the attachment of the patellar tendon. These injuries may be closely simulated by an anatomic variation, due to the persistence



FIG. 18 —Fracture of the neck of the femur with outward rotation of the shaft upon the head

of separate centers of ossification, which do not fuse with the body. They usually lie along the upper and outer margins but at times they occur on both the outer and inner margins. They have smooth surfaces and a fairly good cortex on the side toward the body, as distinguished from the absence of a cortex in fractures. Furthermore, since the condition is frequently bilateral, both knees should be taken for comparison.

The patella normally presents grooves and ridges on its anterior surface which must not be mistaken for fractures.

Vertical projections of the patella made with the knee and thigh flexed, a film against the anterior surface of the tibia, and the tube centered above and in front of the hip, will give information in cases of vertical fractures which cannot be secured in any other way.

Hip.—The line of fracture may or may not be visible. It may appear as a line of increased or diminished density, depending upon whether or not impaction is present. Care should be taken to obtain a true anteroposterior view. If the femur is rotated, the



FIG. 19.—Vertical view of the same fracture showing the relation of the head to the neck.

shadow of its neck will be shortened and distorted. To ensure this position, it is only necessary to make certain that the patient's foot lies in the anteroposterior plane during the exposure.

To determine the extent of anteroposterior displacement, it is necessary to have vertical films.

Vertical views of the neck of the femur are best made as a routine with the sound leg dropped off the radiographic table. The injured foot is inverted as far as possible and the incident rays, defined by a small cone, enter the inner surface of the injured thigh, close to

the perineum. They are directed along a line parallel to and 1 in below Poupart's ligament, in the median plane of the thigh. The cassette is held parallel to the neck of the femur above the iliac cre

In the operating room, shock-proof apparatus must be used and the tube placed between the patient's legs, which are abducted. This view is most important as it enables the surgeon to determine the position of the fragments of the neck after reduction and

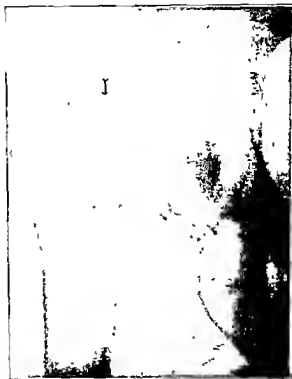


FIG. 20—Old ununited fracture of the neck of the femur. Note the absorption of the neck, and the absence of callus formation.

control the position of pins or other apparatus used for fixing the fragments. This view reveals the extent of the anteroposterior displacement, the amount of comminution in intertrochanteric fractures, and the relative position of the head and neck in intracapsular injuries. It is particularly useful in determining the position of the head in cases of slipped epiphyses in adolescents.

When fracture of the femur occurs above the intertrochanteric line, it is within the joint capsule, and heals without the formation

of visible callus. When there is any displacement of the fragments, there will be a disturbance of the smooth, regular curve formed by the upper margin of the obturator foramen, the inferior border of the neck of the femur, and the inner margin of the shaft. Note the right hip in Fig. 24.

In the prognosis of hip fractures, the possibility of failure of union and of absorption of the neck of the femur must always be kept in mind.



FIG. 21.—Greenstick fracture of the tibia and fibula, with considerable callus formation suggesting periostitis.

The vitality of the head can be inferred from its density. A viable head will become decalcified to the same degree as the surrounding bone, while if not alive its density will be equal to or greater than that of normal bone.

Long Bones.—Fractures of these bones usually present all the roentgenographic evidence of fracture, namely, a fracture line, a

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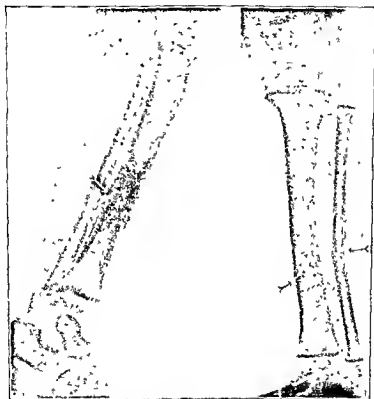


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Long Bones.—Fractures of these bones usually present all the roentgenographic evidence of fracture, namely, a fracture line, a

break in outline, and deformity. An exception is the greenstick fracture of childhood, in which buckling of the cortex occurs and the line of fracture is absent, or seen as a line of increased density. As healing takes place in these fractures, there is the formation of a variable amount of callus. For this reason, a lesion which has been overlooked at the first examination may become visible at a later one.



Anteroposterior view.

Lateral view.

FIG. 22—Subperiosteal fracture of the tibia. The line of fracture is not visible, but there is a definite break in outline in the anteroposterior view only.

In order to obtain undistorted views of these injuries, the tube should be centered over the fracture, with its central ray at right angles to the long diameter of the bone, otherwise, foreshortening will occur, and the deformity will be exaggerated. In properly taken films, the amount of deformity usually appears less than it actually is, for only occasionally do the central rays form a right angle with the point of greatest deformity. Films taken to demon-

strate the result of corrective procedures should, as far as possible, be made in the same position as the preceding ones.

Fractures readily occur, even on muscular exertion, where the bone has been weakened by the presence of cysts, malignant disease or a constitutional disease, such as osteomalacia or osteopsathyrosis, and in Paget's disease. These fractures usually heal well except

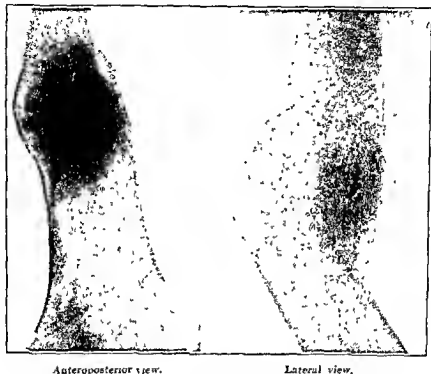


FIG. 23.—Old fracture of the femur, with extensive callus and deformity. The amount of the deformity is seen in the lateral view.

those through malignant tissue and they may heal temporarily if the diseased area receives adequate x-ray therapy.

It must be remembered that callus may be confused with osteogenic tumors on the microscopic slide, and that once callus has formed, experienced pathologists may be unable to decide whether the specimen came from a healing fracture or an early stage of malignant disease.

DISLOCATIONS.

Dislocations are most common in the shoulder, elbow, wrist and hips. In the larger joints, there is never any doubt about the diagnosis.

Subcoracoid dislocations of the shoulder frequently have an associated fracture of the greater tuberosity, which is reduced when the head of the humerus is replaced.



FIG. 24.—Congenital dislocation of left hip.

In posterior dislocation of the shoulder, the anteroposterior view shows only a slight widening of the space between the anterior margin of the glenoid and the articular surface of the humerus. Stereoscopic films or a vertical projection will demonstrate that the head of the humerus is rotated backward with the lesser tuberosity in the glenoid and the main portion of the head behind the scapula.

In the elbow, the typical lesions are backward displacement of the ulna and radius upon the humerus, or anterior dislocation of the head of the radius. The latter is often associated with fracture of the shaft of the ulna.

In the carpus, dislocations may be suspected when the anteroposterior view shows a loss of the normal, clear zone of articular



FIG. 25 —Dislocation of the shoulder-joint. *A*, glenoid cavity; *B*, articular surface of the head of the humerus.



FIG. 26 —Dislocation of semilunar and fracture of cuneiform. Note the concave, distal surface of the semilunar at *b*, the disturbed relations of the articular surfaces at *c*, and the fracture at *a*.

cartilage about an individual bone. This is due to the fact that it overlaps one or more of the adjoining bones. The semilunar bone is the one most commonly affected. The condition is readily demonstrated by a lateral view.

Dislocation of the head of the femur may be posterior or anterior and is commonly the result of severe injury.

Dislocations may occur at any joint. They are usually obvious and require no particular description. In any dislocation, careful search should be made after reduction, as well as before, for associated fractures which may have been overlooked.



FIG 27.—Separation of femoral epiphysis following slight trauma. Perfect reposition by abduction and complete healing

Epiphyseal Separations generally involve a fragment of the adjoining shaft. When unaccompanied by a fracture of the shaft, they can only be diagnosed by the abnormal relations of the epiphyses, which may be only slightly displaced. Films of symmetrical parts should always be taken to check these findings. When these separations are promptly and accurately replaced, there is rarely any interference with the growth of the bone.

Some children who are usually overweight develop a spontaneous

separation of the head of the femur. In such individuals it is usual to find the epiphyseal zone of the opposite hip wide and somewhat hazy or ragged, indicating an underlying disturbance of ossification.

The head of the femur may be floated free from the shaft and become a sequestrum, as the result of an acute infection in young children.

Osgood-Schlatter's Disease.—A partial separation of the tibial tubercle occurs in similar individuals. The tubercle is elevated from the diaphysis and the margins of the epiphyseal line beneath



FIG. 28 —Osgood-Schlatter's disease. Note the soft-tissue swelling about the lesion.

it are thickened and ragged. The soft tissues overlying it are usually swollen and increased in density. A similar injury may occur to the epiphysis of the os calcis (see Subchondral Necrosis, p. 112).

Congenital dislocations of the hip may be single or double. They are characterized by shallowness of the acetabulum, displacement of the head of the femur upward and backward upon the ilium, flattening and deformity of the head, an external rotation of the head and neck upon the shaft of the femur, and the formation of a false acetabulum.

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CHAPTER IV.

BONE PATHOLOGY.

NORMAL bones are smooth and regular in outline. The cortex is homogeneous, and the cancellous tissue is of uniform consistency. The thickness of the cortex and the texture of the spongy bone vary considerably with the individual. The cortex is thickest along the center of the shaft of the long bones, diminishing toward the ends to a thin line which continues beneath the articular cartilage. The roentgenologist should have a good idea of the normal thickness of the cortex of each individual bone.

Bone disease manifests itself by changes in size, outline and density. Various forms and combinations of these changes result from the action of pathologic agents, so that it is often difficult from the roentgen findings alone to identify positively the causative factor. For this reason, the clinical history should always be combined with the roentgen findings in making a diagnosis.

Bones are increased in size in osteomyelitis, tumors, Paget's disease, syphilis and cystic disease. They are diminished in size as a result of trophic disturbances, paralysis, chronic disease of neighboring joints, and developmental anomalies. Changes in outline result from periosteal deposits, callus formation, and tumors.

Changes in density may be either local or diffuse. Diminished density (increased radiability) occurs as a result of disuse, infection, or actual destruction from involvement by tumor, cyst or surgical intervention. Increased density occurs as a diffuse process in old osteomyelitis, syphilis, Paget's disease and osteosclerosis. It is found locally about low-grade infections and carcinomatous metastases of slow development.

In the presence of a pathologic process in bone, the following points should be determined: (1) what bones are involved and what part of each bone, (2) whether the process is primarily within the cortex or within the medulla; (3) whether its margins are sharply defined or otherwise; (4) is the lesion confined to the shaft or does it invade the epiphysis or joint; (5) is it destructive, proliferative, or both; (6) is there associated disease of the soft parts? (7) age of the patient; (8) duration of symptoms.

Periosteal New Bone Formation.—Periosteal new bone formation is due to any form of irritation—most commonly an inflammatory process in its vicinity. Sometimes the earliest evidence of a low-grade osteomyelitis is the presence of a slight periosteal elevation overlying it. *The same is true of neighboring soft tissue infections.*

Lactic periostitis is well known, but the fact that tuberculous bone lesions may at times cause periosteal proliferation is not generally recognized. Any of the low-grade infections, such as typhoid, actinomycosis, leprosy, yaws and coccidiosis may cause localized or extensive deposits of new bone.

Trauma in the form of repeated local injuries or extensive bruising or stripping up of the membrane will be followed by calcification beneath it. Periosteal reaction in callus formation is quite typical. Its presence may call attention to previously undiagnosed fractures. Hemorrhage as seen in scurvy and hemophilia may be the causative factor.

There may be wide-spread periosteal proliferation in lues, rickets and pulmonary osteo-arthritis. Various bone tumors cause deposits at their margins as a result of irritation, or show extensive calcification within their substance.

INFECTIONS.

Osteomyelitis.—The characteristics of a pyogenic process are: (1) a variable amount of destruction of medulla and cortex; (2) an extensive reaction of the periosteum whenever involved; and (3) sequestration and irregular sclerosis. It may attack any bone at any age, but it rarely extends beyond the epiphyseal line.

The process may exist one or two weeks without producing any changes whatever in the shadow of the affected bone, and then areas of diminished density will appear at the site of involvement. Proliferation of the periosteum occurs as a result of irritation beneath it, and may become extensive as more of the bone is involved, leading ultimately to the formation of a shell of new bone, the involucrum, about the necrotic mass of the old shaft, which then becomes a sequestrum. The process may involve only a portion of the shaft, in which case a variable amount of irregular sclerosis appears about the affected area, and small sequestra may be seen.

Two atypical forms are the virulent or fulminating type, and the non-virulent bone abscess. The former may give very little positive roentgen evidence, or it may show extensive, irregular rarefaction

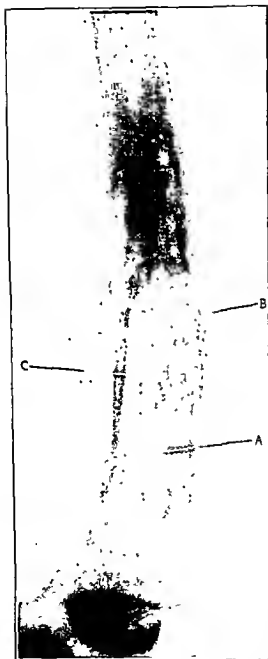


FIG. 29.—Osteomyelitis of shaft of femur. Note the areas of active infection in the medulla at *A*; the involucrum formation at *B*; and the portion of old cortex at *C*, showing the increased density characteristic of sequestrum formation.

throughout the bone with elevation and thickening of the periosteum, but no sclerosis, or new bone formation. The clinical picture is obvious. The non-virulent type shows a circumscribed area of rarefaction in the medulla, generally surrounded by a wall

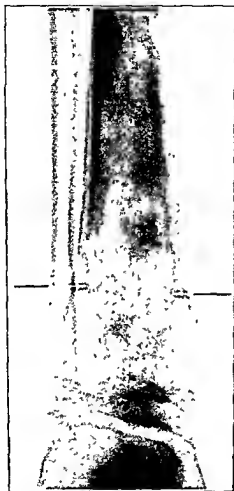


FIG. 30.—Osteomyelitis of low-grade activity.

of increased density, and with a variable amount of proliferation of the overlying periosteum depending upon the depth of the lesion.

This new bone may attain considerable thickness in long-standing lesions and it is often laminated. This appearance has been mistaken for malignant disease of bone.

Tuberculosis—This disease appears in the bones as a slowly progressive, local, destructive process, with little or no regeneration. It most commonly attacks the joints or epiphyses in young individuals, and is less common in the shaft. The early stages may show merely effusion in the affected joint, but rarefaction of the neighboring bones soon occurs, resulting in the characteristic blurred, hazy picture with loss of detail, and, perhaps, local areas



FIG. 31.—Chronic low grade tuberculosis. Note the soft tissue swelling and the enlargement and squaring of the epiphyses.

of destruction in the affected epiphyses. In the carpus and tarsus, this rarefaction may be severe, so that the bones appear of the same density as soft tissue, with finely penciled outlines.

Due to chronic synovial irritation, enlargement and squaring of the epiphyses may occur, with little or no evidence of bone destruction. Ultimately there is more or less destruction of the joint surfaces, resulting in ankylosis as the process heals. Periostitis may

develop in the neighborhood of tuberculous lesions, particularly when secondary infection has occurred.

As the process continues, there is increasing destruction of the subarticular bone with a tendency to spare the articular cartilage, which differentiates the process from a pyogenic infection in which early destruction of the joint cartilage is the rule.



FIG. 32.—Tuberculosis of the acetabulum showing the characteristic scalloped margin.

In children destructive and proliferative lesions in the long bones suggestive of syphilis are sometimes encountered.

Localized tuberculous pockets are also seen in the medulla near the ends of the long bones, particularly the tibia and femur. There is nothing about their appearance to distinguish them from any other low-grade infection. Osteomyelitis or syphilis will produce identical lesions.

Tuberculous processes are prone to develop in multiple foci which fuse, giving a lobulated appearance to the outline of the diseased area (see Figs. 32 and 34) which is diagnostic.

In the spine tuberculosis usually begins in the neighborhood of the intervertebral discs, and destroys the adjacent body or bodies, causing them to collapse, and thus produce a kyphos. The affected portion of the spine is often surrounded by the fusiform shadow of a prevertebral abscess, which later may show evidence of calcification.

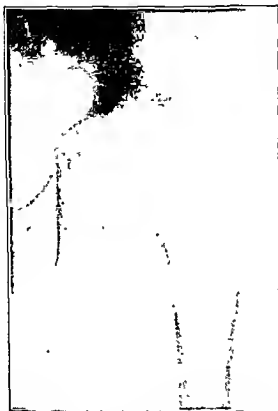


FIG. 33—Early tuberculosis of the hip. Note the slightly enlarged epiphysis of the femur, and the beginning destruction in the acetabulum above it

Tuberculosis of the sacroiliac joint is extremely rare as a primary lesion. It is usually part of a generalized process and occurs more often in young adults than in children.

Although tuberculosis is usually a disease of childhood, it should not be forgotten that it is common in the aged.

Tuberculosis simplex cystica is the name given to multiple small rounded or oval areas of rarefaction in the bones of the hands, feet

or ankles, usually associated with tuberculosis elsewhere, particularly in the skin.

Caries sicca is a slow, destructive process which is most common in the shoulders. It causes irregular erosion of the joint surfaces and the epiphyseal end of the humerus. There is no decalcification.



FIG. 34 —The same hip as shown in Fig. 33 taken seven months later (with no treatment in the interim). There is now extensive destruction of the acetabulum and head of femur, with a small abscess extending into the pelvis. The head of the femur has been displaced inward. Note the irregularly scalloped appearance of the superior margin of the acetabulum.

Dactylitis (*spina ventosa*) is characterized by considerable increase in the diameter of the diseased phalanx, which shows extensive areas of destruction in the medulla. The cortex may be somewhat thin, or slightly increased in thickness. This condition is differentiated from syphilitic dactylitis by the fact that the enlargement in the latter is due to periosteal proliferation, with the formation of a collar of new bone outside of the old cortex and com-

paratively little involvement of the medulla. However, differentiation of the two conditions is at times extremely difficult from the roentgenogram alone.

Syphilis.—Syphilis of bone is a destructive and proliferative process, assuming varied forms which may simulate other conditions. It attacks any bone at any age. Its commonest manifestations are periostitis and irregular areas of destruction.



FIG. 35.—*Caries sicca*. Note the destruction of the head of the humerus

Periostitis is usually limited to the shaft, and the picture varies according to the age and activity of the process. It usually extends to the epiphyseal lines (Fig. 41). When acute, the appearance is that of multiple distinct, thin laminæ laid down upon the old cortex. As the condition becomes more chronic, these laminæ become thicker and more compact, so that ultimately the area involved becomes as dense as the normal cortex. At the same time, the surface loses its fringy character and becomes smooth, although it may be more or less irregular. This increase in thickness of the cortex will often give an appearance of bowing, as is seen in the so-called "saber shin." It should be noted that this thickening of the cortex usually occurs on the convex side of the curve, whereas

in rickets it appears on the concave side. There is often an endosteal proliferation with *narrowing of the medullary canal*.



FIG 36

FIG. 36.—Congenital syphilis.



FIG. 37

FIG. 37.—Congenital syphilis. Note the thickened cortex of the tibia, and the typical areas of rarefaction within it.

Periostitis may also occur as small, local elevations of the periosteum (bone blisters) near the ends of the long bones, or may assume

the form of multiple confluent, small blisters. There is another type of lesion, a sort of lacework pattern, which consists of strands of calcified material which run out at right angles to the cortex and arch together at their terminations. Running through this pattern, parallel to the shaft and midway between the cortex and the periphery, there are definite thin sheets of calcification. At the margins of the process where it blends into the normal bone there is the usual



FIG. 38.—Syphilitic process involving the lower end of the tibia and fibula.

type of laminated periosteal thickening. This type of periostitis is sometimes mistaken for periosteal sarcoma. In the congenital form, the periosteum may become separated from the shaft for a considerable distance, leaving a clear space between it and the cortex.

More or less sharply circumscribed areas of increased radiability may be found in the new periosteal bone (see Figs. 37 and 39).

Syphilis and yaws are the only diseases known to lay down periosteal new bone and then excavate rarefied areas within it.

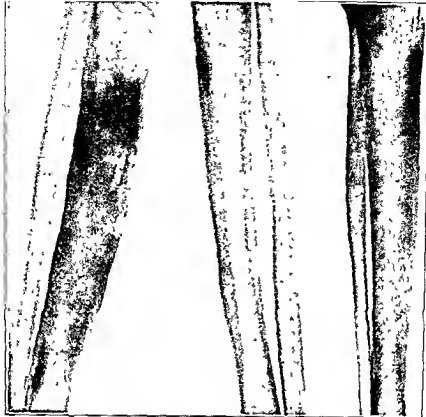


FIG. 39.—Types of syphilitic periostitis of the tibia

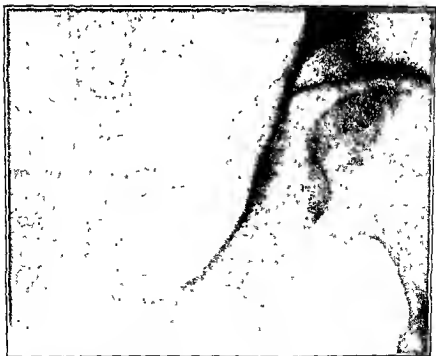


FIG. 40—Gummatous lesion of the pubis. Under treatment, this area showed considerable regeneration of bone in four months and practically normal structure in one year.

Irregular areas of destruction may occur in any bone, usually as a result of gummatous changes (Fig. 40). In the skull, the picture is striking, and represents "punched-out" areas involving both the



FIG. 41—Syphilitic periostitis which resembles osteitis deformans. Note the absence of enlargement of the epiphysis of the tibia.

outer and the inner tables, or multiple moth-eaten patches. In the long bones, gummata are generally associated with periosteal changes, although at times a bone may be riddled with these areas of rarefaction and show only slight periosteal change. This is par-

ticularly common in the acute cases. In children a common picture is the juxta-epiphyseal lesion, which occurs in the diaphysis near the epiphyseal line. It is characterized at first by an irregular loss of substance close to the epiphyseal line, and, perhaps, a slight periostitis. With healing the affected area becomes sclerosed, leading to the formation of a white line at the epiphysis, which is thicker than that seen in scorbutus. As a result of this process, there may be a characteristic angulation of the epiphysis upon the shaft, due to contraction of the diseased area, or interference with growth at this point.

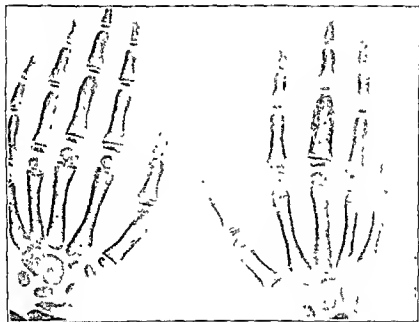


FIG. 42 — Syphilitic dactylitis.

Joint lesions may be unilateral or symmetrical. Ordinarily, little is seen beyond an increase in density in the soft parts, due to effusion and synovial thickening. Later on, low rounded hypertrophic growths may appear about the margins of these joints. Extensive destructive processes may sometimes occur in the epiphyses of long bones, causing considerable deformity. Localized areas of destruction suggesting tuberculosis may be found in the epiphyses of children.

In the spine, lues causes the destruction of one or more bodies, generally preserving the intervertebral discs. The affected area is

often surrounded by calcified masses of detritus. Extensive hypertrophic changes are seen on the neighboring vertebrae.

Typhoid.—The lesions in bone due to the typhoid bacillus are destructive and proliferative, usually occurring in early adult life.



FIG. 43.—Coenosis in a child

They are characterized by circumscribed areas of destruction in the ribs, the margins of vertebral bodies, and, occasionally, the cortex of long bones. There may be a local periostitis, and, at times, extensive irregular periostitis indistinguishable from that of

syphilis. In the spine, the first roentgen evidence generally appears at an interval of weeks or months after the onset of symptoms, at which time a small area of destruction may appear in the corner of a vertebra close to the disc. Subsequently coarse hypertrophic bridges may appear about this area, with thinning of the disc, or the intervertebral cartilage may be destroyed, with a resulting fusion of the adjacent vertebrae.

Yaws.—Yaws is a chronic tropical disease which manifests itself in the early cases (one to two years) in the form of multiple oval areas of rarefaction scattered through the long bones. These areas vary in size and degree of translucency. A characteristic finding is the presence of these cavities within the cortex, often just beneath the periosteum which may be slightly elevated and thickened over the lesion. The process also attacks the articular surfaces with erosion of the bone beneath the cartilage, and considerable deformity if the process is extensive. In the chronic cases, there is marked irregularity in size and outline of the bones, and considerable shortening, if the epiphyses have been involved.

Actinomycosis.—Actinomycosis causes a chronic osteomyelitis. It usually occurs in the jaw, but may invade the vertebrae, ribs or ilium. It is characterized by its slow course, and by the pronounced proliferation of bone, with the resulting general increase in density.

Madura Foot.—Madura foot is a rare disease of the tarsal bones, resembling actinomycosis. It runs a course of years with extensive destruction and new bone formation.

Coccidiosis.—Coccidioides is a chronic granuloma due to the *Oidium coccidium*. It usually occurs in patients living in the central valleys of California and appears first in the bones of the pelvis and extremities. It is most commonly confused with tuberculosis or malignant disease. It does not attack joints as frequently as tuberculosis, and the clinical course will usually differentiate it from malignant disease. Involved areas show irregular destruction sometimes accompanied by mild or marked periosteal lesions, suggesting syphilitic periostitis.

Leprosy.—Leprosy is characterized in its early stages by bone atrophy of the terminal phalanges, and a variable amount of periostitis. As the disease progresses, these phalanges disappear, and there is a progressive involvement of the other phalanges.

Smallpox.—In smallpox destructive lesions have been noted in the joints and epiphyseal ends of the long bones, resulting in ankylosis of the joints affected.

Parasites—*Echinococcus* cysts may occur in bone, causing indefinite rarefaction in the medulla, which may be mistaken for osteomyelitis or osteosarcoma. The usual sites are ilia, sacrum, femur, humerus or tibia. One case has been reported in a lumbar vertebra.

Phosphorus Poisoning.—Phosphorus poisoning causes a chronic osteomyelitis of the jaw, indistinguishable roentgenologically from the ordinary pyogenic form.



FIG. 41.—Coccidioides of the hum.

Radiation produces a dry necrosis similar to that seen in phosphorus poisoning. It occurs as an industrial hazard in the use of radium paint and in patients who have received heavy radium treatment. The bone dies, becomes dense but does not sequestrate. There is an absence of the involucrum formation seen in phosphorus poisoning, and no tendency to heal.

BONE TUMORS.

In the study of *bone neoplasms*, the most important question to decide is whether the lesion is benign or malignant. This may

be a matter of considerable difficulty. With increasing experience, and particularly as a result of the careful work being done by the Registry of Bone Sarcoma, progress has been made toward a rational classification of these processes.



FIG. 45.—Multiple cartilaginous exostoses. Note the thin exostoses on the femur due to bone formation in old chondromata. A large mass of mixed bone and cartilage has been removed at A.

There are many border-line and atypical lesions which are not clean-cut either roentgenologically or pathologically. The histologic appearance of a growth may change considerably during its development, and specimens from different parts of the same

tumor may show different characteristics, making the diagnosis from a single specimen unreliable.



FIG 46.—Osteochondroma of the tibia. Note the lobulated appearance of the tumor and that it has a pedicle.

Benign Lesions.

Exostoses.—Exostoses are merely irregular extensions of normal bone into the surrounding tissues. They are characterized by very slow development, by the fact that their structure is that of normal bone, and that they blend into the bone at their sites of origin. They may appear in any portion of the skeleton, but are most commonly found near the ends of the long bones.

They occur in different shapes, varying from thin, hook-like processes to broad rounded masses. Their structure may be ivory-like or spongy.



FIG. 47.—Multiple enchondromata

Multiple Cartilaginous Exostoses.—Multiple cartilaginous exostoses are an hereditary anomaly of growth, in which irregular outgrowths of cartilage and bone appear in the regions of the epiphyseal lines. These tumors usually involve many of the long bones, causing considerable deformity.

Osteoma and Osteochondroma.—These are true bone tumors, and follow a slow but progressive course. They contain variable amounts of bone and cartilage, and are classified accordingly. They

arise from the cortex upon a broad base or narrow pedicle, and often present a cauliflower-like appearance, with transparent nodules of cartilage scattered throughout the mass. They never invade bone but may destroy it by pressure.



FIG. 48.—Benign, giant-cell tumor of the astragalus, showing the characteristic trabeculation, and the absence of involvement of the joints and soft tissues

Enchondromata.—Enchondromata cause irregular asymmetrical enlargements of bone. They are usually multiple, but may occur singly and are most common in the hands, feet and long bones where they develop near the ends of the shafts. There is considerable distortion in the outline as a result of tumor growth, with or without thinning of the cortex, and the trabeculae of the medulla may be replaced by a homogeneous, putty-like shadow, or by multiple, small, rounded areas of rarefaction. In extensive tumors, the thinning of the cortex may be so extreme that it is reduced to small, thin flakes of bone on the periphery of the growth, which in a single film are projected upon the tumor, and must be differentiated from calcification within the growth. Chondromata may be confused with giant-cell tumors and myelomata.

Calcification in enchondromata is responsible for some of the irregular strands of calcified material found at times in the medulla of the long bones, particularly the lower third of the femur.

Giant-cell Tumors.—Giant-cell tumors are most frequent between the ages of fifteen and thirty. Their favorite locations are the lower ends of the radius and femur, upper end of the tibia, vertebral

bodies, pelvis, mandible, and tarsus. They are the most common tumors about the knee-joint in young adults. These tumors are of slow growth. They do not invade the regional lymph glands, or metastasize to distant parts, and neither do they recur after removal, except in rare instances. They may extend along fascial and muscular planes into adjacent bones, or protrude into a joint, but do not invade the surrounding tissues.



FIG. 49 — Giant-cell tumor.

In rare instances giant-cell tumors have become malignant after curettement or irradiation. In the roentgenogram these tumors appear as a central, single lesion in the epiphyseal end of a long bone, or occupying most of the substance of a cancellous bone. One rarely sees simple cysts in cancellous bone or giant-cell tumors outside of it. They tend to grow equally in all directions, but in a number of cases the greatest extent is along the medullary canal, the path of least resistance. There is a bulging of the cortex, rarely a break. The intact cortex is an important point in differentiating

the benign from the malignant tumors. The soft tissues are not invaded except in cases where a fracture has occurred. The process does not cross the articular cartilage but goes readily through the epiphyseal cartilage differing thus from osteogenic sarcoma and myeloma which may begin in the shaft near the epiphyseal cartilage but seldom cross it. In adults the lesion is almost invariably in the epiphysis, and extends toward the joint surface where it is sharply limited. These tumors apparently start very close to the epiphyseal



FIG. 50.—Cystic type of giant-cell tumor

line and advance toward the joint. The shadow of the involved area, as seen on the roentgenogram, has a characteristic appearance. The bone is widened, with lobulated outline. It is more radiant than the surrounding structures, and divided by many trabeculae. They vary considerably in size, and in the clearness with which they can be demonstrated. The process does not invade the neighboring soft tissue, but may extend along ligamentous attachments, and, in this way, involve the adjoining bones. A characteristic finding is

extension of the process into bony projections, as, for example, the condyles of the femur, or the various processes of the vertebræ.

Early in their development these growths may occur as simple rarefied areas in the bone, with hazy margins but no trabeculæ, when they have been mistaken for bone cysts. However, their location should prevent this error. This appearance may be due to their rapid growth, and the fact that they have not had time to develop the characteristic trabeculæ.

Lesions of this sort have been seen in the tibia, femur, radius and the phalanges.



FIG. 51.—Bone cyst in upper end of humerus.

FIG. 52.—Bone cyst and fracture.

Benign, giant-cell tumors must be differentiated from myeloma, malignant osteogenic tumors of central origin, and from simple bone cysts.

Single myelomata closely resemble giant-cell tumors. They show identical trabeculation, expansion and thinning of the cortex. However, they are apt to occur later in life. They are most common in the scapula, spine or ribs. In the long bones they occur

the benign from the malignant tumors. The soft tissues are not invaded except in cases where a fracture has occurred. The process does not cross the articular cartilage but goes readily through the epiphyseal cartilage differing thus from osteogenic sarcoma and myeloma which may begin in the shaft near the epiphyseal cartilage but seldom cross it. In adults the lesion is almost invariably in the epiphysis, and extends toward the joint surface where it is sharply limited. These tumors apparently start very close to the epiphyseal



FIG. 30.—Cystic type of giant-cell tumor.

line and advance toward the joint. The shadow of the involved area, as seen on the roentgenogram, has a characteristic appearance. The bone is widened, with lobulated outline. It is more radiant than the surrounding structures, and divided by many trabeculae. They vary considerably in size, and in the clearness with which they can be demonstrated. The process does not invade the neighboring soft tissue, but may extend along ligamentous attachments, and, in this way, involve the adjoining bones. A characteristic finding is

either in the shaft or near the ends, but they do not cross old epiphyseal lines to reach the articular surfaces.

Malignant osteogenic tumors are not trabeculated. They do not extend along bony processes or ligaments, but burst through the cortex, invading the surrounding tissues.

Bone Cysts.—Bone cysts occur in the long bones and in the jaw. They are a common lesion in the upper humerus in children. They are not trabeculated, and seldom expand the bone. The process is



FIG. 53.—Osteitis fibrosa.

entirely within the shaft, and spreads longitudinally in the medulla, without involving the cortex, which, however, may be considerably thinned from pressure. There is no deformity in outline unless a fracture has occurred. Spontaneous fractures are often the first indication of the presence of a lesion, and they are usually followed by extensive callus formation and disappearance of the cyst. Following repeated trauma it is not unusual to find small cysts developing in cancellous bone, probably the result of localized hemor-



FIG. 54.—Fibroma of fibula.

multiple cysts, which vary in size and shape. There is considerable expansion of the bone, and spontaneous fractures are common as the result of the thinning of the cortex. There is no periosteal proliferation. This condition is most common in the femur. Some cases resemble myeloma; other cases show an appearance very

rhage. The carpal bones, particularly the scaphoid and semilunar are the ones most commonly affected.

Osteitis Fibrosa.—Allied to cystic disease is a rare condition which may involve one or all of the bones. It consists in the replacement of the normal structure by irregular strands of trabeculae, enclosing

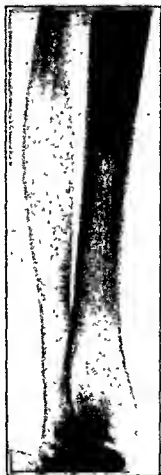


FIG. 54.—Fibroma of fibula.

multiple cysts, which vary in size and shape. There is considerable expansion of the bone, and spontaneous fractures are common as the result of the thinning of the cortex. There is no periosteal proliferation. This condition is most common in the femur. Some cases resemble myeloma; other cases show an appearance very

similar to osteitis deformans. Any patient showing the presence of one or more bone cysts should be carefully examined for evidence of parathyroid tumors or disturbances in calcium or phosphorus metabolism.

Fibroma.—Fibroma is a rare benign growth which occurs in the long bones. It expands the shaft, causes thinning of the cortex and shows fine trabeculation throughout its extent. It pursues an extremely chronic course.

Hemangioma.—Hemangiomas are slow growing lesions in spongy bone which begin as a rarefied area with hazy trabeculae suggesting a giant-cell tumor. In older lesions the trabeculae become prominent, sufficiently differentiating the two conditions. As the tumor grows the cortex is expanded with it and thinned, while the trabeculations become heavier. In the spine they seldom cause any change in the outline of the bone but the trabeculae are rearranged with a characteristic accentuation of the vertical bands.

Myxoma.—Myxoma is a benign lesion often found in the phalanges. It appears as a localized cyst-like area. The differentiation between cyst, chondroma, myxoma and giant-cell tumor in the phalanges is extremely difficult.

Malignant Bone Tumors.

Primary malignant tumors of bone occur in youth and early adult life, generally before thirty years of age. They often present misleading symptoms, such as a history of injury (in one-half the cases), an acute onset, with pain at night, a somewhat increased local and general temperature and leukocytosis.

Osteogenic Sarcoma.—Sarcoma of bone is generally a rapid-growing tumor which metastasizes early through the blood stream to the lungs. Very few cures have been obtained by any method of treatment. Early diagnosis is of the greatest importance, and the correct interpretation of the roentgen finding is perhaps the most important factor.

These tumors appear as single lesions in the shafts of long bones, generally in individuals under thirty. They may be osteoblastic, osteolytic or both. They do not cross cartilage or invade joints, but do destroy the cortex of the involved bone, early invading the surrounding soft tissue, producing a soft-tissue tumor which is visible on the film. There are four main types anatomically:

1. Fibrocellular, which is chiefly periosteal.

2. Telangiectatic, involving marrow cavity, cortex and periosteum.

3. Sclerosing, involving all portions of the bone.

4. Undifferentiated sarcomata.

Roentgenologically the first three tend to merge into one general group, as a single neoplasm may show characteristics of all three divisions.



FIG. 55

FIG. 55—Early osteogenic sarcoma. Note the irregular erosion of the cortex beneath the soft-tissue tumor as indicated by the arrows.



FIG. 56

FIG. 56—The same case as in Fig. 55 (film taken six weeks later). There is now a large, soft-tissue tumor containing calcified strands.

Fibrocellular.—This is a tumor arising in the inner layers of the periosteum, extending along and enclosing the shaft. It remains encapsulated by the periosteum for periods varying with the character of the growth. Tendon insertions offer marked resistance to its progress. In the early stages, the roentgen appearance is that of slight erosion and mottling of the affected cortex, surrounded by a soft-tissue swelling, which is quite suggestive of a beginning osteomyelitis. With increase in the size of the tumor, the erosion of the cortex increases, and periosteal proliferation becomes evident at the limits of the growth upon the shaft. This is a very characteristic finding. Strands of calcified material are seen radiating out-

ward through the tumor, producing the so-called "ray-formation." This is the form which has been quite generally called "periosteal." Other members of this group show more medullary involvement, and may contain a mixture of cartilage or mucoid material. They are then sometimes classified as chondro- or myxosarcomata.

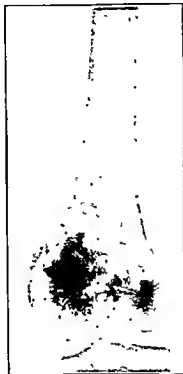


FIG. 57.—Osteogenic sarcoma.

Telangiectatic.—This form is characterized by an extensive development of bloodvessels throughout the growth, with arteriovenous aneurisms which may be sufficiently large to cause the mass to pulsate. As might be anticipated, the prognosis in this type is extremely bad. There is considerable absorption of bone, and the lesion advances rapidly. Frequently the more solid portions of the growth show calcified strands similar to those seen in the previous group.

Sclerosing.—The appearance of these tumors is due to the production of dense bone within the tumor, so that in typical cases a mass of ivory-like density obliterates the marrow cavity, and pro-

duces a more or less fusiform swelling about the shaft. They are generally slow-growing, and, as a rule, do not metastasize early. On the film, they present dense, cottony shadows resembling somewhat *benign osteochondroma*, but they do not arise from a pedicle, or contain trabeculated bone.



FIG. 59.—Osteogenic sarcoma (lateral view). Note the periosteal reaction at A (anteroposterior view).

Undifferentiated.—This group of tumors is entirely osteolytic. In the roentgenogram, they show only loss of substance, and no bone proliferation. Histologically they are composed of round cells which show no tendency to produce any definite structure.

Endothelial Myeloma (Ewing's Tumor).—Endothelial myeloma is a tumor occurring usually between the ages of five and twenty-five years. It is particularly common in the tibia and fibula.

One form resembles osteogenic sarcoma and probably is often diagnosed as such. The lesions are situated somewhat farther from the ends of the long bones, there is more cortical destruction and much more periosteal new bone formation, which may appear in

layers partially or completely surrounding the tumor. There may be spicules of bone running perpendicularly to the cortex, but again they are apt to be heavier than those seen in osteogenic sarcoma.



FIG. 59 — Type of Ewing's tumor sometimes seen in the long bones.



FIG. 60 — Ewing's tumor of the fibula.

Another form of this tumor, illustrated in Fig. 59, produces a fairly uniform expansion of the affected bone and a coarse trabecular structure behind an advancing area of rarefaction.



FIG. 61.—Sclerosing type of osteogenic sarcoma in upper portion of femur.

The most frequent metastases, as shown by the roentgen-rays are to the lungs, skull, spine and scapula. The tumors respond readily to radiation but the patients rarely live more than five years.

The process may be confused with osteomyelitis because of intermittent swelling, pain, heat, temperature and leukocytosis.

Carcinoma.—Carcinoma is always metastatic in bone and is generally multiple. It may involve any one or all of the bones. It is not common in the extremities below the elbows and knees, affecting them only in cases of wide-spread and generally slow-growing metastasis. It produces a moth-eaten appearance of the bone, due to the irregular destruction of bone substance and its replacement by tumor mass. The cortex may be involved, but ordinarily only in the later stages. There is no periosteal reaction, and no change



FIG. 62.—Primary chondrosarcoma of the right sacroiliac joint.

in outline, unless spontaneous fracture occurs. In the skull, it appears as irregular areas of bone destruction, which typically are limited to the diploë, and do not involve either table. When the spine is involved, there is more or less extensive destruction of several bodies, but ordinarily they do not collapse, owing to the fact that the dense tumor tissue affords considerable support. This is of importance in the differentiation from tuberculosis, lues and myeloma, in which collapse of the affected bodies is the rule.

There is a second form of metastatic carcinoma generally secondary to a tumor of the prostate or breast, which is of extremely slow development—cases having been seen ten years after the recognition of the primary disease. It is characterized by the extensive production of dense bone in the vicinity of the lesions. Its usual site is in the spine, pelvis and ribs, which become greatly increased in density, and coarsely mottled from the intermingled areas of rarefaction and condensation. The lesions may be confused with



FIG. 63.—Undifferentiated sarcoma. The process is purely destructive.

osteitis deformans. The long history may also be suggestive of this condition. More careful inspection will show that the picture is produced by adjacent areas of bone destruction and proliferation, with the latter predominating, and that there is no evidence of the rearrangement of trabeculae into bundles, which is typical of *osteitis deformans*. In *osteitis deformans* the bones are enlarged and may be bowed. Absence of enlargement suggests carcinoma. Metastatic

carcinoma is seldom seen in the extremities below the elbows or knees.

Other Bone Tumors.—Almost any type of tumor may be encountered in the bones, and the roentgen appearance of different patho-



FIG. 64.—Metastatic carcinoma. Note the areas of destruction in the wing of the ilium, in the ischium, and in the neck and trochanter of the femur. All are common sites of involvement.

logic entities is naturally very similar, as they are manifested only by irregular areas of bone destruction, which are not characteristic of any particular neoplasm. They are commonly diagnosed as carci-

noma roentgenologically. Under this heading are: hypernephroma, endothelioma, myeloma, lymphosarcoma, etc. The age of the patient and the distribution of lesions may be helpful.



FIG. 65.—Metastatic hypernephroma of clavicle and scapula.

Hypernephroma.—Hypernephroma may occur as a single or multiple bone lesion. Its distribution throughout the skeleton corresponds to that of red bone-marrow. It is particularly common in the skull, sternum, ribs and bodies of vertebrae. Single lesions are easily mistaken for osteogenic sarcoma when the primary growth is not evident. They not infrequently produce a bulging of the cortex, or destroy it, invading the surrounding soft tissue, and, in this respect, they differ from other metastatic tumors. They are characterized by local areas of rarefaction, loss of trabeculae and absence of new bone formation.

Myeloma.—Myeloma is a slow-growing, malignant tumor usually limited to cancellous bone. It is found chiefly in the ages between forty and sixty years. Single lesions show coarse trabeculation identical with that seen in giant-cell tumors, but the latter occur in the ends of the long bones while myeloma is more common in

the shaft. A favorite location in older people is the spine and ribs. When located near the ends of the long bones they do not extend across the level of the old epiphyseal lines. This is the type of lesion usually classified as the plasma-cell variety. Owing to its slow growth, deformities in outline occur as a result of thinning and expansion of the cortex overlying the growth. For the same reason, spontaneous fracture is fairly common. Multiple myelo-

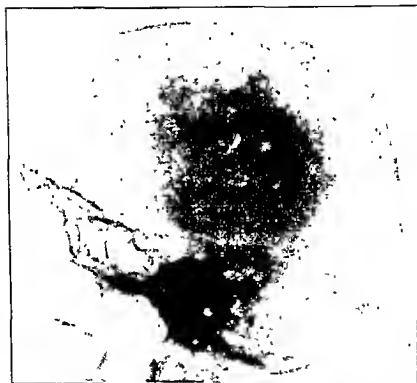


FIG. 66 — Multiple myeloms. Note the fine small areas of diminished density with rather hazy outlines scattered throughout the skull.

mata are more common. Their appearance resembles that of metastatic carcinoma, but the areas are finer and hazier in outline. Lesions in the skull are more characteristic (Fig. 66). The distribution is similar, favoring the ribs, sternum, vertebrae, skull, pelvis, scapula and humerus. They may be accompanied by the presence of Bence-Jones albumin in the urine. Some cases have responded well to roentgen therapy for a time.

Chloroma.—Allied to myeloma and the leukemias, is a form of tumor which occurs in the skull, usually in the vicinity of the orbit, and in the vertebrae, ribs and long bones. It is seen most frequently in childhood, and, occasionally, after forty. It runs an acute course and is usually fatal. However, the lesions are very sensitive to radiation and some cases are well eight years after onset as a result of careful roentgen therapy. An indefinite area of rarefaction appears in the temporal or frontal regions sometimes accompanied



FIG. 67.—Plasma-cell myeloma (single lesion).

by separation of sutures and other evidence of increased intracranial pressure. Secondary lesions soon develop elsewhere in the skeleton. At first they are purely destructive, but a periosteal reaction occurs over them as they reach the surface and this new bone formation is greatly increased by roentgen treatment.

Malignant Lymphoma.—Malignant lymphoma appears as a patchy rarefaction of the type seen in any metastatic malignant in bone. It occurs most commonly in the spine, ribs and pelvis. Affected

vertebral bodies usually collapse to some extent. These lesions are prone to occur in the late stages of the disease, although apparently primary bone foci have been observed.

Neuroblastoma.—These tumors frequently involve the skull in children and young adults, producing multiple areas of destruction resembling metastatic carcinoma in older persons. (See Fig. 68.)



FIG 68 —Neuroblastoma

Leukemia.—Several cases of lymphatic leukemia in children and young adults have shown slight irregular erosion of the cortex near the ends of long bones and occasional areas of destruction in the medulla on the shaft side of the epiphyses.

Anemia.—The spongy bone containing red marrow (ribs, spine, ends of the long bones and the skull) may show coarse trabeculation in the course of any chronic anemia, as the result of hypertrophy of the blood-forming elements.

In a particular form of anemia occurring in children of Mediterranean parentage, the bones become rarefied, with a transparent medulla containing finely penciled trabeculations, with large inter-spaces.

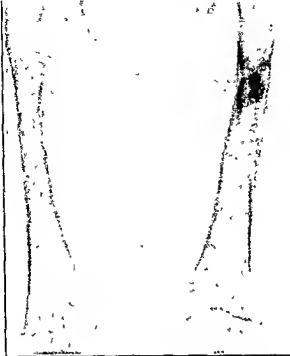


FIG. 69.--Neuroblastoma.



FIG. 70.--Erythroblastic anemia.

The skull presents an increase in size of the cranial bones, with thin tables, and a spongy diploic structure.

As the process continues, striations develop within the calvarium, perpendicular to the tables, giving a characteristic picture.

A similar appearance is seen in sickle-cell anemia.



FIG 71.—Malignant lymphoma involving the body of the third cervical vertebra.

DISEASES OF NUTRITION.

Scurvy.—This condition is commonly seen during the first years of life, and may or may not have an associated rickets. The earliest evidence of its presence is a thin white line in the shaft margin of the epiphyseal zone. This line is thinner, denser and more sharply defined than the one seen in rickets. It tends to spread out into the soft tissues beyond the line of the shaft. Very frequently irregular areas of rarefaction several millimeters in diameter appear in the shaft, at the junction of the cortex and epiphyseal zone. Later, in the clinical course, subperiosteal hemorrhages appear as more or less extensive irregular elevations of the peri-

teum along the shafts of the long bones. In severe cases, the hemorrhage may be sufficient to produce separation of the epiphyses. The final process consists of organization of the clot, which produces a shadow of considerable density about the shaft.



FIG. 72 —Scurvy, well advanced. Note the organized hemorrhage about the shaft at A, and the white line at B.

Differential diagnosis is from lues, lead poisoning and osteomyelitis. In lues the process is more generalized, the periosteum is less elevated, and epiphyseal dislocation does not occur. In osteomyelitis there is destruction of the shaft, which is unaffected in scorbutus. The clinical picture is generally characteristic. In lead poisoning the dense line at the end of the shaft is thicker than in scurvy and there are no subperiosteal hemorrhages.

Rickets.—This is a disease usually occurring during the first dentition and affecting mainly the bones which are growing rapidly

when the process begins. The skull and thorax are first involved, later the long bones. In the roentgenogram, one sees a flaring and widening of the diaphysis above the epiphyseal line, and the zone between the shaft and epiphysis is increased in thickness, with ragged, fringy margins (Fig. 73, A). The trabeculae in the spongy bone are coarse and prominent. The shaft side of the epiphyseal



FIG. 73.—Active rickets. Note the ragged epiphyseal line at A, and the coarse trabeculation at B.

zone may appear as a transverse homogeneous band $\frac{1}{4}$ to $\frac{1}{2}$ inch wide. As healing occurs this hard recalcifies and produces a dense white line along the central margin of the epiphyseal cartilage. The shaft may be bowed, and the cortex considerably thickened on the concave side of the curve. Mild periosteal proliferation sometimes occurs. There are areas of decreased density in the cranial bones accompanied by prominences of frontal and parietal bosses.

In true rickets the changes are confined to the ends of the bones and enlargement and rarefaction are not noticable.

Renal Rickets.—Renal rickets is a disease of bone association with chronic interstitial nephritis occurring in children. The



FIG. 74 —Bowling of the tibia in an adult, due to rickets during childhood.

characteristic changes are at the epiphyseal lines. The epiphyseal zone is increased in thickness and the margins of the shafts adjoining them are somewhat cupped and ragged. The metacarpals and phalanges may be involved in the more severe cases.

In the marked and chronic cases the bones acquire the appearance of an osteomalacia, with thin cortex, coarse spongy trabeculation, wide irregularity and haziness of the epiphyseal ends of the shafts.

The cancellous tissue is coarse and the cortex is thinned in the spine, the vertebral body may present an appearance seen in the vertebrae of fishes. The upper and lower surface of each body is concave and the intervertebral spaces fusiform.

Lead Poisoning.—Children who have eaten paint containing lead off their cribs or toys, or who have ingested lead in any other way, show dense bands across the shafts of the long bones at the epiphyseal lines, due to a deposit of lead. The thickness of the band depends upon the length of exposure and the amount ingested.

BONE CHANGES DUE TO GLANDULAR DYSFUNCTION.

Hyperpituitarism.—Overactivity of the anterior lobe before puberty causes gigantism and after the epiphyses have closed, acromegaly.

In gigantism the bones are elongated and enlarged. Otherwise the changes differ from acromegaly only in degree.

In acromegaly there is a progressive enlargement of the face, hands and feet, accompanied by a spherical expansion of the sella turcica, due to the pituitary tumor. The floor of the sella turcica is thinned and the chnoid processes are deformed by pressure. The facial bones are enlarged, with a marked increase in size of the air-spaces, and the mandible is elongated. The bones of the hands and feet are enlarged and show characteristic tufting of the terminal phalanges. The general structure of all the bones is coarse and heavy.

Hypopituitarism.—Hypopituitarism causes retarded development, resulting in dwarfism or infantilism, with a sella turcica which is small or on the low side of normal.

Hyperthyroidism.—There is an increased rate of development in children, resulting in a somewhat advanced bone age. Adults may show a slight amount of decalcification in the cancellous bone.

Hypothyroidism.—Hypothyroidism causes delayed development, evidenced by the retarded appearance of ossification centers and the late closure of epiphyseal lines.

The parathyroids are of greater importance because of their control of calcium metabolism.

Hyperparathyroidism.—Hyperparathyroidism gives rise to increased mobilization of calcium from the bones, which become rarefied, with thin cortical margins and fine widely-spaced trabeculae.



FIG. 75.—*Achondroplasia.*

Stones are readily formed in the kidneys from an increased calcium excretion. The bones usually show cyst formation, which may be localized or widespread. These cysts differ from simple cysts in that they may occur in any part of any bone and they are often

asymmetrical. They vary greatly in size and some resemble the early stages of giant-cell tumor.

Spontaneous fractures are common. Advanced cases show a loss of height, due to softening of the vertebrae and bowing of the long bones, with compression deformities in the pelvis and skull. The bodies of the vertebrae are biconcave and the intervertebral spaces are widened, producing the so-called "fish vertebra."

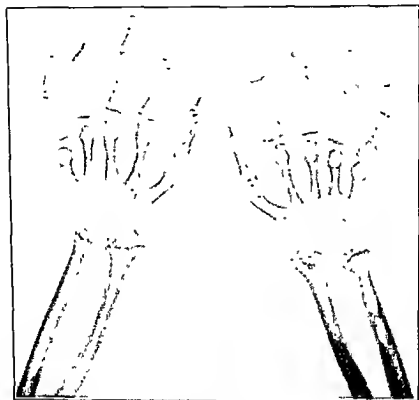


FIG. 76.—Abnormal epiphyseal development due to endocrine disorder; patient aged twenty-one years.

The disease is subject to periods of remission, when recalcification occurs.

The calcium which is mobilized from the bones may be deposited wherever an acid reaction is present, as in the kidneys, lungs and the wall of the stomach.

Hypoparathyroidism.—Hypoparathyroidism gives rise to a dense, heavily calcified skeleton.

Achondroplasia (Chondrodystrophia Fetalis).—The bones in this condition are shortened, compact, and, at times, bowed. The epiphyseal line is very thin and sharply defined, and closes considerably earlier than the normal. This results in an adult whose long bones are very much shortened, with corresponding loss of height. In



FIG. 77.—Spine in osteochondrodystrophy.

the carpus and tarsus, the cancellous structure is rather coarse and the cortex thin. This process is said to involve only those bones in which ossification has begun before the sixth month.

Allied to achondroplasia is a condition which has received the name of *chondro-osteodystrophy*, in which the patients seldom exceed 1 meter in height, owing to a delayed and distorted development of

the epiphyses and vertebral bodies. There is a characteristic irregularity in the outline of the carpal and tarsal bones. As far as they have been observed these patients do not reach beyond a bone age of twelve or fifteen years.



FIG. 78.—Osteogenesis imperfecta.

Osteogenesis Imperfecta (Fragilitas Ossium, Periosteal Dysplasia or Osteopsathyrosis).—In the infantile form of this disease, the bones show great diminution in lime salts and thinning of the cortex, without changes in size. This results in a weakening of the structure of the bones, and multiple spontaneous fractures occur, usually followed by a fair amount of callus formation. A characteristic

feature is the appearance of the skull, the calvarium of which is composed of a great number of small plaques of bone irregularly united by fibrous tissue, presenting a mosaic appearance.

In the adult form of the disease, the bones are nearly normal in size and calcium content, but generally present considerable deformity as a result of the multiple spontaneous fractures which the patient has suffered. These patients often have blue sclerotics and progressive otosclerosis.



FIG. 79.—*Osteitis deformans*.—Note the characteristic trabeculation in the sacrum and both femoral necks

Osteomalacia.—*Osteomalacia* as used clinically refers to a form of bone softening with decalcification, resulting in bending, bowing and fractures. It is a generalized disease, most common in pregnant women, as the result of dietary deficiency and absence of sunlight. The bones are transparent and the trabeculae large and coarse. The long bones are bowed and may show multiple fractures. The appearance is similar to that seen in disturbance of calcium metab-

olism, due to overactivity of the parathyroids. Stones are often present in the kidneys.



FIG 80.—Osteitis deformans.

Osteitis Deformans (Paget's Disease).—Osteitis deformans is a disease appearing in middle age and later. It is a slowly progressive process usually involving the bones of the lower extremities,

the pelvis, spine, clavicles and calvarium; in rare forms it may be limited to one bone. The earliest lesions are, as a rule, in the pelvis. The long bones show thickening of the cortex, with enlargement, bowing and rearrangement of the trabeculae into strands or bundles running longitudinally. The new cortical bone may show multiple longitudinal cyst-like areas similar to those in the medulla. The medulla also shows mottled areas of rarefaction which extend into the epiphyses. This involvement of the epiphyses

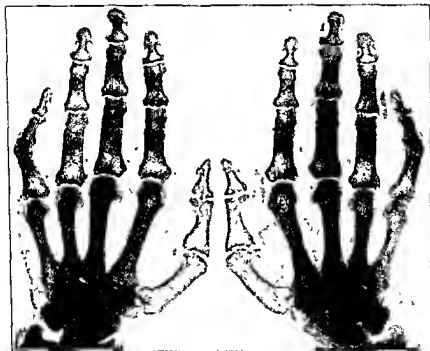


FIG. 81.—Acromegaly. Note the enlargement of the terminal phalanges

is important in the differentiation from lues, which very rarely affects the epiphyses in the same manner. In the skull this condition causes an increase in the size of the head as a result of expansion of the cranial bones, which show great thickening of both tables and coarse mottling throughout the diploë due to alternating areas of increased and diminished density. In early cases, there may be an extreme rarefaction of a considerable portion of the calvarium. The sharp contrast between the normal bone and the adjacent area of decalcification makes a striking picture. Marked calcification

in the arterial walls is generally associated with this disease. Stone formation in the kidneys is common. Films of the kidney areas should always be included in an examination of a case of Paget's disease.



FIG. 82 — Hypertrophic pulmonary osteo-arthropathy.

OTHER BONE DISEASE.

Hypertrophic Pulmonary Osteo-arthropathy.—This process begins with enlargement of the soft tissues of the ends of the fingers, so-called club-fingers. The terminal phalanges become expanded

at their tips, and proliferation of the periosteum, which is difficult to distinguish from that of lues, appears along the metacarpals and phalanges, particularly those of the fifth fingers and toes, and frequently about the distal ends of the long bones. Rarely the process may involve all the periosteum of the long bones. As a result, these bones have a thickened cortex and, in the later stages, are increased in width. The joints are also involved in late stages and show erosion of the joint cartilage, spur formation, and even ankylosis. The disease is associated with chronic infection or malignant disease of the lungs.



FIG. 83.—Osteopoikilosis Woman, aged thirty-five years. Never any bone symptoms.

Osteosclerosis (Marble Bones).—A rare hereditary disease in which the bones throughout the skeleton of both children and adults are found to be so dense as to reveal *no internal structure whatever* on the roentgenogram. The long bones are not enlarged, but they are unusually fragile and spontaneous fractures are common. Heal-

ing is not delayed. A secondary anemia may be present from restriction of the marrow spaces.

Melorheostosis.—Melorheostosis is a similar process in which dense areas of calcification appear along one margin of a long bone or along one segmental area of distribution in an extremity.

Osteopoikilosis.—Osteopoikilosis is an hereditary disease in which many small rounded or oval areas of compact density are found scattered through the cancellous tissue of the skeleton. In some areas these spots tend to lie with their long axes following the main trabeculae. The condition is usually found accidentally and is of no clinical importance.



Fig. 51.—Osteochondritis of the scaphoid (Köster's disease.) Flattened scaphoid indicated by arrow. Normal foot on right.

Hemophilia.—The skeletal evidences of this disease are due to subperiosteal hemorrhage, causing a diffuse elevation of the periosteum, suggesting a low-grade inflammatory process, and recurrent hemorrhages into the joints, particularly the knee and elbow. These result in thickening of the soft tissues and erosion of the joint surfaces.

In children squaring and enlargement of the epiphyses may be seen similar to that occurring in tuberculosis.

Subchondral Necrosis (Osteochondritis).—This disease includes a large group of lesions usually referred to under the names of the men who first described them. The disease is usually local but may be generalized. The involved bones first show haziness and irregularity in structure, followed by sclerosis, fragmentation and flat-

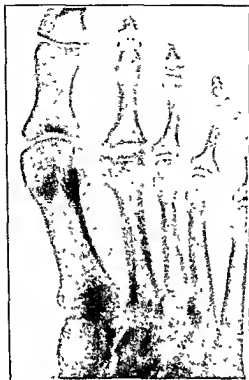


FIG. 85.—Osteochondritis of the distal end of the second metatarsal (Freiberg's disease).



FIG. 86.—Subchondral necrosis of the head of the right femur. (Legg's disease.)

tening. Cyst-like areas may appear in the diseased bone. The affected bones usually heal in time, causing varying degrees of deformity.

The process appears in different locations at various ages, depending upon the time of appearance of the ossification centers. Any bone in the body may be involved. It is an aseptic necrosis resulting from an interruption of the normal blood supply.



FIG 67 — Gaucher's Disease.

A common form is the condition known as Legg's or Perthes' disease, a flattening and fragmentation of the femoral head in children which in its early stages may be mistaken for tuberculosis. However, in this condition, the diseased bone maintains a better density and there is less of the general haziness and joint destruction so characteristic of tuberculosis. The clinical course is quite different and the process tends to heal in the course of a year or so, with

a residual flattening of the head and usually an increase in the width of the neck of the femur.

The process was described by Kohler as occurring in the tarsal scaphoid in boys between the ages of three and nine years. Kohler and Freiberg called attention to a similar change in the head of the second metatarsal, seen usually in girls near the age of twenty years. The articular end of the distal extremity of the bone becomes flattened or even concave and may be irregular in outline and increased in density. The adjacent portion of the shaft is increased in width but the joint space is not affected.

Kienboeck's name has been given to a form of the disease developing in the semilunar bone some weeks or months after an injury. It usually occurs in individuals with a relatively short ulna.

Calvé described the appearance of this lesion in the epiphyses of the vertebral bodies, and more recently Rogers and Cleaves have shown that it may affect the epiphyses of the sacroiliac joints; the lesion occurs in children in their teens and is commonly mistaken for tuberculosis.

Similar changes have been described in the epiphysis of the os calcis, the patella and in the capitellum of the humerus.

Gaucher's Disease.—Gaucher's disease is a rare congenital and familial disease seen mostly in young females of the Jewish race. In addition to enlargement of the liver and spleen, pigmentation of the face and hands, and a hypochromic anemia, there is a rarefaction and cortical thinning of the spongy bone. The areas most commonly affected are the vertebrae, femurs and tibia. The lower thirds of the femurs are characteristically expanded and the trabecular structure is coarsely meshed, owing to the presence of masses of large Gaucher's cells which replace the normal marrow. The vertebrae may collapse as in osteomalacia.

TROPHIC CHANGES.

Senile Atrophy.—The bones of old people share in the general atrophic changes of the body. They are less dense, the cortex is thinned, and the spongy bone becomes delicate in structure. Ultimately, there is a gradual decrease in the size of the bone. The process begins in areas devoid of muscular attachments, and involves most extensively the flat bones, especially the calvarium, pelvis, and scapulae.

Osteoporosis.—The term “bone atrophy” has been commonly, though erroneously, employed to designate a process of rarefaction in bone. An area of bone, following injury, fixation or infection in its vicinity, may lose a large portion of its density and become radiolucent. This process may be acute, coming on within a few days after injury; but it more commonly requires from ten days



FIG. 88.—Trophic changes in the fourth and fifth toes following old fracture of lumbar spine, with previous operative removal of phalanges of second and third toes.

to several weeks for its development. It occurs in two forms—the *spotted* and *diffuse*. The *spotted* form consists of multiple small areas of rarefaction, from a millimeter to a centimeter in diameter, scattered through the affected bone. These areas may remain discrete with fairly normal bone substance between them, giving a picture similar to that of metastatic malignancy; but usually the intervening bone gradually becomes rarefied, producing

a diffuse decalcification throughout the affected area. The diffuse form is commonly seen in extremities after fixation for some weeks, or involving the bones about an infected joint, or in the bones of the hands and feet in cases of infection of the overlying soft parts. As its name implies, it is a uniform loss of density which ordinarily includes several bones either wholly or in part. The mechanism of these changes is not well understood, but seems to be in some way connected with the circulation.

Changes Associated with Nerve Lesions.—The most common example of this condition is the Charcot joint which occurs in tabes and syringomyelia, where there is complete disorganization of the joint, with extensive destruction of the articular ends of the bones, and the occurrence of multiple loose fragments scattered through the joint. There is no diminution in density in the affected bones, in fact, there may be an increase.

The shrinkage and ultimate disappearance of the terminal phalanges in leprosy has been mentioned. In long-standing cases of fractured vertebræ, the phalanges of the toes may progressively diminish in size and ultimately disappear. There is also erosion of the articular ends of the metatarsals. A similar process has been observed in a case of diabetes without obvious nerve changes. Rarefaction of the bones and thinning of joint spaces of both hands has been noted in connection with scleroderma. In Raynaud's disease there may be shrinkage and gradual disappearance of terminal phalanges.

A TABULATION OF THE FINDINGS IN THE MORE COMMON BONE LESIONS FOR USE IN DIFFERENTIAL DIAGNOSIS.

OSTEOMYELITIS.

1. Usually a single lesion.
2. Both destructive and proliferative.
3. A disease of the shaft, involving the epiphyses—rarely the joint.
4. Produces bone atrophy and sclerosis.
5. Usually starts in the medullary portion and involves the cortex, periosteum, and soft tissue.
6. Occurs at any age.
7. Enlargement and deformity of the bone.

TUBERCULOSIS.

1. Usually a single lesion.
2. A destructive process.
3. A disease of the joints and epiphyses.
4. Rarely invades the shaft and soft tissues. The neighboring bones show marked atrophy. The periosteum is usually not involved.
5. More common in children.
6. The size of the bone may be small, due to interference with growth.

A TABULATION OF THE FINDINGS IN THE MORE COMMON BONE LESIONS FOR USE IN DIFFERENTIAL DIAGNOSIS.—(Continued)

STYRILIS

- 1 Usually a multiple process
- 2 Usually proliferative. The gummatous form, which is rare, is both proliferative and destructive
- 3 Usually a disease of the shaft, and rarely involves the joint and epiphysis
- 4 Usually confined to the periosteum, but may involve the cortex, does not cause bone atrophy
- 5 May appear at any age
- 6 There may be enlargement and considerable deformity of the bones.

MYELOMA.

- 1 Single or multiple lesions
- 2 Trabeculated.
- 3 Do not involve epiphyses characteristic skull changes
- 4 Late adult life

CARCINOMA.

1. Multiple lesion.
2. Usually purely destructive, rarely there is bone proliferation about the invaded area.
- 3 Attacks the medulla and cortex of the long and flat bones; the periosteum and joints are not involved
4. A disease of adults.
- 5 In the proliferative type, the bones may be enlarged and deformed

OSTEOGENIC SARCOMA

1. Single lesion
- 2 Both destructive and proliferative
- 3 Involves the distal third of the shaft, rarely the epiphysis, never the joint.
- 4 The cortex of the bone is destroyed and the soft tissues invaded
- 5 Usually in young adults

PAGEY'S DISEASE.

- 1 A multiple lesion.
- 2 Proliferative.
- 3 Involves the shaft and epiphysis—the joints are not affected.
- 4 Late adult life.
5. Overgrowth of the bony structures and abnormal trabeculation; the soft tissues are not invaded.
- 6 Bones are enlarged and may be bowed.

GIANT-CELL TUMOR.

1. Single trabeculated lesion.
- 2 Destructive type
3. Involves the epiphysis and the end of the shaft, the cortex may be thinned, but is not invaded, the joints and soft tissues are unaffected.
4. Childhood and adult life.
- 5 The bone is locally deformed.

BONE CYST.

- 1 Single lesion.
2. Purely destructive.
- 3 Located in the medullary portion of shaft; does not invade the cortex, joint, or soft tissue
4. Children and young adults
- 5 The bone is not deformed.

OSTEOCHONDROMA.

1. Usually a single lesion with pedicle.
2. Purely proliferative
- 3 Arises from the cortex; never invades the bone.
4. Common in children and young adults.
5. There may be some deformity of bone from pressure; structure of the growth contains normal bone.

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CHAPTER V.

THE SKULL.

ROENTGENOLOGY of the skull, its contents, sinuses, mastoids and teeth has become a field of its own. There is naturally a close association between the teeth and sinuses, and the two should always be studied together. The bones of the skull are subject to fractures and diseases affecting the skeleton generally, which have previously been considered to some extent.

Fractures of the calvarium are readily recognized if extensive—the sharp, dense black, clean-cut lines of linear breaks being obvious. Only when they follow bloodvessels lines, or extend into sutures, is there difficulty in the diagnosis. Small venous channels in the frontal region, and the irregular suture lines below and behind the mastoids are often mistaken for fractures. This mistake can be avoided by taking the opposite side for comparison. Depressed fractures and fractures of the inner or outer tables may be represented in the lateral film by slight changes in the bony structure. Therefore, suspicious areas should always be checked by tangential views taken from at least two different angles (see Figs. 12 and 13). It should be remembered that the middle meningeal grooves are filled largely by the veins which lie between the bone and the artery, and that relatively small injuries involving these grooves may cause extensive slow venous hemorrhage. Fractures of the base, even though of considerable extent, will be overlooked in routine lateral views. Various vertical projections of the base are necessary to demonstrate them.

Fractures due to falls from a standing position are usually linear and run *meridianally* through the calvarium. Stellate or comminuted fractures are due to the impact of a solid object or a fall against a sharp, hard object. Repeated blows with a blunt weapon cause multiple fine linear fractures in both tables and finally a depression of one or more fragments after the tables have been sufficiently weakened.

Ring fractures of the base, partly or completely encircling the foramen magnum, follow falls from a great height or in conditions where the vertebrae tend to be thrust up through the base of the skull.

It is not good practice to submit a patient, suspected of having a fractured skull, to a prolonged and tiresome roentgen examination within a few hours of the injury, when his symptoms are due mainly to hemorrhage or damaged brain. Such investigations are much more satisfactory when the acute symptoms have somewhat subsided.

Fracture lines may persist for from six months to two years after an injury. In children they tend to disappear earlier than in adults.



FIG. 69 —Syphilis of calvarium.

The most common infections are osteomyelitis and lues. The former is generally a low-grade, slowly progressive process arising from a sinus infection, rarely from a wound. It is likely to be stubborn and difficult to eradicate. In the early stages the roentgen examination may be negative, but when the infection is well developed it causes a moth-eaten appearance in the bone, with ragged margins. There is no new bone formation. Not infrequently the infection extends along the diploic veins, producing new areas of destruction entirely distinct and separate from the original area of the abscess.

Lues cause protean lesions. They may be ragged, irregular, destructive processes giving a moth-eaten appearance suggestive of metastatic malignant disease. A variant of this form is the occurrence of multiple clusters of fine, punctate rarefactions forming patches a centimeter or more in diameter. Others will cause considerable new bone formation and will appear as scattered areas of irregularly increased density. The frontal bone has long been known as a common site for luetic lesions. A point which sometimes helps in the identification of the process is that the lesions tend to involve the outer table, whereas malignant disease, being blood-borne, more often invades the diploe. Tangential films are therefore helpful.

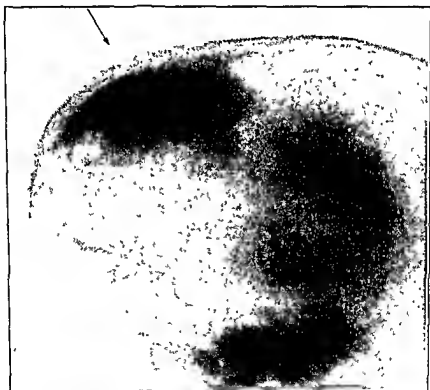


FIG. 90.—Localized hyperostosis of frontal region indicated by the arrow.

Hyperostosis.—The frontal region is at times the seat of a localized overgrowth of bone, a hyperostosis which may be stationary or slowly progressive. It may be the result of a low-grade infection, hemorrhage, or a true tumor formation. Headache is a common symptom.

A similar affection has long been known under the name of leontiasis ossea or creeping periostitis. It may be localized about the sinuses or nasal fossæ, or spread slowly over the maxilla, frontal and parietal regions. Usually the mandibles are involved. There is a tremendous overgrowth of masses of ivory-like bone, with soft tissue thickening over them. The condition may be confused with Paget's disease.



FIG. 91.—*Osteitis deformans.*

Malignant Disease.—Carcinoma, hypernephroma and myeloma produce destructive lesions, which are multiple, arising in the diploë. These are usually associated with other lesions in the body which establish the diagnosis.

Sarcoma may develop in the calvarium or base, and does not differ from sarcoma in other flat bones.

Neuroblastoma.—Neuroblastoma is a tumor, occurring in children under twenty years, usually primary in the suprarenals, but it may have its origin in any part of the sympathetic nervous system. It metastasizes early to the skull and other bones. In the skull the process resembles the metastases from carcinoma. The areas of

bone destruction are finer and have a more mottled appearance; and in addition, there is a periosteal reaction in most cases. Clinically, in addition to the changes in the bones, there may be protrusion of one or both eyes with discoloration of the lids, a profound secondary anemia develops and an abdominal tumor may be felt.

Chloroma.—Chloroma related to myeloma and leukemia, and so called from the yellowish or greenish color of the growth, appears in the form of a destructive lesion near the orbits or sinuses.

Any soft tissue tumor may cause erosion of the bone in proximity to it, *e. g.*, cirroid aneurism and cholesteatoma. The latter is a benign tumor. Most often seen in the temporal regions, they may cause extensive destruction of bone. The margins of the involved areas are sharply defined and quite dense.

Endothelioma of the dura, when it involves the bone, produces a characteristic, coarsely granular area surrounded by large diploic veins with fine spicules of new bone formation in the tumor mass.

Osteitis deformans affects the skull in various ways. At first there may be an almost complete decalcification of a large portion of the calvarium. Usually there is a marked overgrowth, leading to progressive enlargement of the head. This is due to diffuse thickening involving both cortex and diploë, sometimes one more than the other. Usually small areas of increased density are scattered throughout the affected area. Other portions of the skeleton, notably the pelvis, are practically always involved (see Figs. 79 and 80).

Defects in the cranial bones, vertebrae, pelvis, ribs and even long bones sometimes associated with diabetes insipidus and exophthalmus are due to deposits of lipoid material or cholesterol. The condition has been called xanthomatosis.

There is a rare deformity of the new-born associated with meningocele and encephalocele, in which the skull presents a smooth outer surface, with cyst-like areas, separated by radiating bony ridges on the inner surface. This condition is supposed to be due to fetal hydrocephalus.

Erythroblastic anemia, a disease of childhood, causes an increase in thickness of the calvarium, marked rarefaction, thinning of the cortex and coarse trabeculation in the diploë. In the later stages vertical striations within the diploë presents a striking picture (Fig. 92).



FIG. 92.—Erythroblastic anemia.



FIG. 93.—The short steep skull base often seen in mental defectives. Note that the distance between the auditory canal and the nasion is less than one-half the total anteroposterior diameter of the skull.

Sutures.—There is great variability in the time and sequence of closure of the sutures; normally they are open until at least thirty-five. The posterior end of the sagittal suture begins to close at forty, and the coronal at fifty. Closure early in life (craniostenosis) gives rise to deformities in shape, depending upon the sutures involved. Three general forms are recognized:



FIG. 94.—Oxycephaly. The suture lines and the grooves of the bloodvessels are obliterated.

1. Turret head (one form of which is oxycephaly, Fig. 94) which is short, broad and abnormally high. The roentgen picture is striking, for, in addition to the unusual shape with a projection at the bregma and bulging of the temporal regions, there is marked thinning of the vault with deep convolational atrophy which may progress to perforation. Prominence of the eyes and blindness are early symptoms.

2. Scaphoid head, which is abnormally long and narrow.

3. Slanting head, showing marked asymmetry in any one of several planes.

Abnormal separation of suture lines is an evidence of intracranial pressure.

Hydrocephalus.—In hydrocephalus there is enlargement of the vault out of proportion to the base. The picture is one of chronic intracranial pressure, enlargement and great thinning of the vault of the skull, with exaggeration of the convolutional depressions and often separation of the sutures. *Flattening of the sella* is fairly common. In the form due to lues there is less thinning of the skull and a strikingly short base.



FIG. 95.—Endothelioma of the dura showing extensive bone involvement. Note the increased vessel markings and the new bone formation.

Ventriculography reveals marked dilatation of the ventricles with thinning of the cerebral cortex, which at times may be reduced to less than a centimeter in thickness.

Congenital defectives may show a fairly normal calvarium or one which is smaller than normal with an early closure of the suture lines. A striking feature in these children is the short and steep skull base (Fig. 93).

Tumor.—A brain tumor is rarely directly visible. But localized erosion, irregular porosity of the calvarium over the lesion, increased density due to new bone formation in the dura or calcification in the mass itself (which is rare) may help to localize the process. In a high percentage of the cases, all that appears on the film

is the evidence of increased intracranial pressure. The common findings are:

1. In the calvarium: Increased convolutional markings, if the tumor is of slow development; enlargement of bloodvessel channels, if the tumor lies fairly close to the surface; and perhaps localized erosion of the bone; or new bone deposits with spicule formation.



FIG. 96 —Tumor of the frontal region, showing calcification within the mass at A, pressure marks in the calvarium at B, and loss of the posterior clinoid process at C.

2. In the sella: The clinoid processes become pointed and later thinned; the opening is increased in width, and in the later stages there is thinning of the floor of the sella and loss of the posterior clinoid processes. These changes are due to indirect pressure. A considerable percentage of brain tumors will cause recognizable changes in the appearance of the sella.

3. Cerebellopontile angle growths may, by extension, cause erosion and forward bending of the posterior clinoid processes.

4. Displacement of the pineal gland may occur, depending upon the size and location of the tumor. This finding is of considerable value when there is sufficient calcification in the pineal gland to outline it distinctly on the film.

5. Calcification within the tumor.

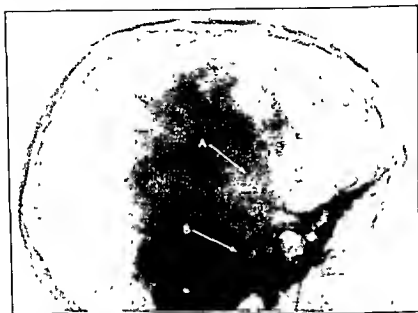


FIG 97.—Supra sellar cyst showing characteristic calcification at A, and loss of outline of the sella at B.

Intrasellar tumors cause spherical enlargement of the sella with thinning of walls and floor, and finally perforation of the floor. As the growth extends into the sphenoidal sinus, a double outline appears, due to the remnant of the old floor and the profile of the mass in the sinus. The anterior clinoids are short and blunt, and the dorsum sella is thinned and pushed backward. No other signs of intracranial pressure are seen until late in the disease. There may be an associated acromegaly.

Some suprasellar tumors, due to cranio-pharyngeal pouch remnants, show delicate spongy, calcified masses immediately above the sella, as well as the signs of increased intracranial pressure.

Acoustic neuromas usually cause an enlargement of the porus acousticus on the affected side. This is best demonstrated on films in the anteroposterior plane with the occiput against the film and the incident rays passing obliquely from above so that the petrous portions of both mastoids are projected above the base.

Encephalography will in some cases give evidence sufficiently definite to localize lesions otherwise undemonstrable. Air is introduced into the spinal canal with the patient upright, and a series of



FIG. 98 —Encephalogram in a normal child showing L, Overlapping lateral ventricles, T, temporal horn of lateral ventricle; 3, third ventricle, 4, fourth ventricle; A, aqueduct of Sylvius, P, pons; C.P., cisterna pontis, C.M., cisterna magna, C.V., cisterna venae magnae cerebri

films taken including lateral and anteroposterior views with the patient upright, prone and supine. Study of the series of films will show changes in outline of the ventricles and evidence of obstruction in the channels connecting the various chambers, as well as obliteration of surface sulci or shrinkage of the cerebrum. The surface markings of the cerebrum are of importance. If they are constantly absent over a definite area with a good filling otherwise, subdural adhesions may be suspected.

In cerebral atrophy, the sulci on the surface are increased in width. Normal channels are not over 2 or 3 mm. wide.

In some cases of local or general atrophy of the cerebrum, large lakes of air may be found between the brain and skull.

Subdural Hemorrhages.—Tumors in the temporal or cerebral lobes usually give characteristic evidence; displacement of the septum pellucidum and pineal away from the lesion and deformation of the lateral ventricle on the same side.

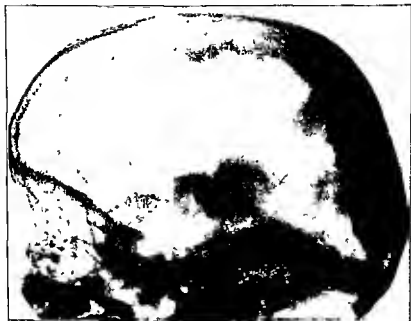


FIG. 99.—There is a considerable area of calcification in a tumor of the pineal gland. The ventricles have been tapped, the fluid drawn off and air allowed to replace it. The outline of the tumor then becomes visible.

A wide experience is necessary in the interpretation of encephalograms or ventriculograms, and most careful correlation with the clinical evidence is essential.

This is a highly specialized field.

Sella.—True lateral views, preferably stereoscopic, are essential for the proper observation of the sella. It varies greatly in size, averaging 10 mm. in the anteroposterior diameter (with limits of from 5 to 15 mm.) and in depth 8 mm. (with limits of 4 to 12 mm.). In shape it is flat, oval or round, with the oval predominating. The

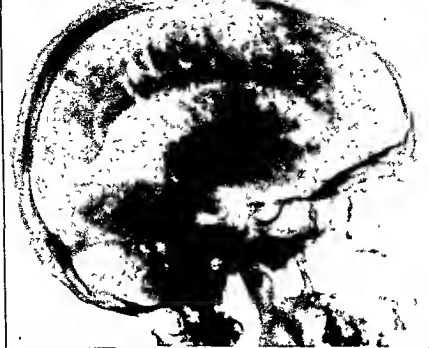


FIG. 100.—Lateral view of the normal skull, and encephalogram.

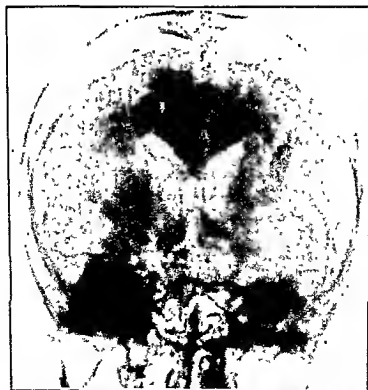


FIG. 101.—An anteroposterior view of the normal skull, and encephalogram.

clinoid processes often overlap on the films, owing either to failure to secure true lateral projections, or to the fact that they extend beyond each other. True bridging is rare and of no significance except as a possible cause of "pituitary" headaches due to expansion of the gland within its rigid shell.

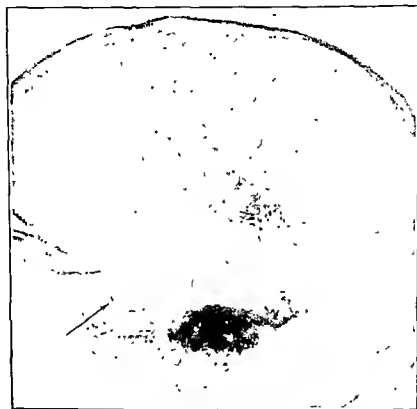


FIG 102—Intrasellar tumor showing thinning of clinoid processes and floor of the sella. There is no other evidence of intracranial pressure.

As already noted, intrasellar tumors produce characteristic deformities in the outline of the space. In acromegaly associated changes are seen in the form of: (1) Enlargement of the sinuses; (2) elongation of the mandible; (3) general increase in the size of the entire skeleton, particularly the hands and feet; and (4) coarsening of the texture of the spongy bone.

Calcification Within the Skull.—Normally about one-half of all individuals over twenty years of age show varying amounts of calcification in the pineal gland, appearing as small dense spots in the mesial plane; they lie about $1\frac{1}{2}$ cm. above the mastoids when seen in lateral views. This finding is of no significance, except in cases of brain tumor or hemorrhage in which displacements of the gland of from 5 to 15 mm. out of the mesial plane have been observed,

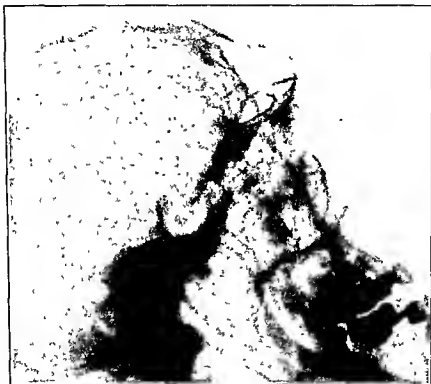


FIG 103 —Acromegaly. Note the elongation of the mandible, large sinuses and enlargement of the sella

even when the tumor lay in the anterior or posterior portions of the brain. Absence of displacement of the pineal gland does not rule out brain tumor, as the lesion may be located below the tentorium in the posterior fossa, or it may be so situated in the frontal lobes as to cause no disturbance of the pineal body. When the calcified mass is large and irregular, a tumor of the pineal gland may be present.

Fine mottled areas of calcification, lying 1 or more cm. behind the pineal gland in the lateral view and about 2 cm. external to it in the anteroposterior projections, are due to calcium deposits in the choroid plexus of the ventricles and should not be mistaken for tumor formation. Usually the process is bilateral.

Calcification in the midline in the anterior portion of the skull is sometimes found as a result of deposits in the falx. In rare cases a thin bony flake of varying size extends inward from the inner table into the falx. Calcification within the walls of the arteries, forming Willis' circle, is sometimes visible in the roentgenogram. Aneurysms of these vessels, when calcified, appear as portions of a circle overlapping the sella in lateral views, but external to it in postero-anterior projections.

Calcification may develop in any of the meninges as a result of infection or tumor growth. When tuberculomas become calcified they produce a round or oval shadow, more sharply defined and of greater density than that seen in tumors.

Sinuses.—For a proper study of the sinuses, anteroposterior, lateral, and vertical projections are necessary. If the films are made with the patient in the upright position, fluid levels will be demonstrated in the frontal sinuses and antra if they are present. The routine anteroposterior film shows the size of the frontal sinuses. These sinuses may be absent, but, as a rule, are present to some degree, and appear as lobular areas of diminished density above the orbits. Their density and the sharpness of the outline of their walls and septa should be carefully noted. Immediately below them on either side, between the septum and the inner wall of the orbit, lie the overlapped shadows of anterior and posterior ethmoid cells, appearing as dark, roughly rectangular areas. They may extend upward over the roof of the orbit, between it and the floor of the frontal sinus, as shown at E in Fig. 104, or they may extend downward into the upper portion of the antrum. There is considerable importance attached to these extensions by the surgeon, for when infected they simulate frontal sinus or antral disease.

Lying across the septum and the lower ethmoid cells, toward the midline, the rather square image of the sphenoidal sinus can be seen, when it is of good size. Below the orbits and outside the lateral walls of the nasal cavity, the roughly triangular antra are shown. The dense shadows of the petrous portions of the temporal bones cross the lower orbit and upper antrum horizontally.

In addition to the outline of the sinuses themselves, there is present some evidence of the shape of the nasal septum, size of the turbinates, and relative depth of the floor of both the nose and the antra.

A variation of this standard position, in which the incident ray is directed downward from a point in the parietal region, projects



FIG. 104.—Very large sinuses Anatomical variations Large supraorbital ethmoid cells at E.

these temporal bone masses below the antra and is particularly useful as a check upon the previous view. Similarly, another position of the tube below the occipital region will direct the incident ray along the floor of the skull, and project the upper portion of the sphenoidal sinus clear of the base, thus permitting an estimate of its opacity and the condition of its membrane.

A vertical projection of the base is sometimes employed for the

demonstration of fractures in this region, and to estimate the extent of the sphenoidal sinuses anteroposteriorly and laterally. For the latter purpose the most satisfactory image may be obtained by placing a large film in the mouth, and focusing the tube above the vertex.

The lateral film is particularly valuable in checking the anteroposterior view of the frontal sinuses, particularly with reference to determining their depth and the thickness of their walls. Teeth, polyps or foreign bodies in the antrum, may be well projected in this view



FIG. 105 —Osteoma in the frontal sinus.

The normal sinus, because of its air content and thin walls, appears on the roentgenogram as a more or less darkened area with sharply defined edges. Any change in the amount of air contained within it, or in the thickness of its walls, will be recorded as a change in density on the roentgenogram, and both these factors must be considered in making a diagnosis. This is particularly true of the frontal sinuses, where a degree of density which is normal for one individual may be quite abnormal for another whose spaces are larger, walls thinner, and whose sinuses should therefore appear darker. For the recognition of disease, it is essential to compare the two sides, and to have a fairly definite mental picture of the appearance of the normal sinus. In the study of the frontal

sinuses, both anteroposterior and lateral views must be studied and compared.

A general haziness with a slight increase in density in one or more sinuses usually means thickening of the lining membrane. This finding may be confirmed in the case of the frontal sinuses by the additional evidence of thickening of the septal markings, which, in disease, become hazy and surrounded by an indefinite zone of slightly increased density, in marked contrast to the sharply outlined normal septa. This general thickening may involve only one sinus, all of the sinuses on one side, or those of both sides. In the last condition, some difficulty may arise from the fact that comparison of opposite sides is impossible, and the roentgenologist must rely upon his knowledge of the normal.

Granulations, pus or tumors produce a shadow of increased density, which generally obliterates the sinus completely. Their shadows are identical in every respect, so that it is impossible, as a rule, to ascertain the causal factor. When there is a fluid exudate in a sinus, it is often possible to make out a fluid level in the suspected cavity upon a roentgenogram obtained with the patient upright. However, the absence of a fluid level does not rule out pus. Tumors of the sinuses generally show some evidence of their nature by erosion or invasion of the walls of adjacent bones. Very rarely a sinus or portion of the orbit will be occupied by a dense osteoma. Absence of frontal sinuses is fairly common, and must be differentiated from thickening which has obscured the margins and obliterated the outline of a well-developed sinus. A lateral view will show no evidence of a sinus and no room for it at the base of the frontal. Careful inspection of the anteroposterior view should show the presence of bone structure in the suspected area.

It must not be forgotten that a sinus may be found filled with mucous material at operation and yet cast a normal shadow on the roentgenogram. In fact, mucocoeles which have eroded the bone overlying them appear as areas of diminished density. This occurs most commonly in the frontal sinuses or ethmoid cells, which may be expanded into the orbit. The surgeon may wash accumulated pus out of an antrum which was perfectly clear on a film made the day before.

Polypi can sometimes be visualized in the frontal sinuses and antra as rounded areas of slightly increased density. The entire sinus will usually appear somewhat hazy as a result of the thickened membrane.

A dense fusiform shadow may overlap the septum in a case of gumma of the septum.

The patency and course of nasal ducts may be determined from roentgenograms made with opaque probes *in situ*, and the course of the lacrimal ducts may be visualized by opaque solutions.

Some surgeons feel that it is necessary to fill the antra with opaque solutions to demonstrate the thickness of the lining membrane or the presence of polyps. In selected cases it is a useful procedure.



FIG 106.—Normal mastoid cells.

Mastoids.—Well-developed mastoid cells have been noted as early as the second year. Their development generally precedes that of the sinuses. Roentgenograms of both sides should always be obtained as a routine for purposes of comparison. Normally, the cells are bright and clear with sharply outlined walls. The broad grooves of the lateral sinus can usually be traced across the mastoid, appearing as a streak of diminished density. In an acute mastoiditis, there is general haziness of the affected cells and blurring of their margins, followed later by destruction of the cells and loss of their outlines, which are replaced by an indefinite area of increased density. In chronic cases, there is more or less absence of cells and a variable degree of sclerosis. Occasionally the mastoid cells fail to

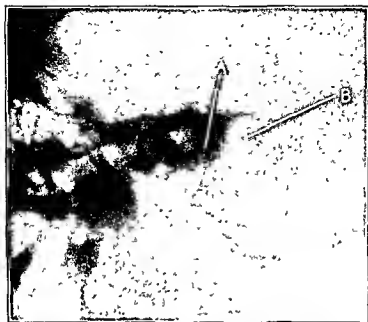


FIG. 107.—Infantile mastoid. Note the density of the bone at *A*, and the groove of the lateral sinus at *B*.



FIG. 108.—Chronic mastoiditis. Note the thickening in the mastoid region, and

develop, and the finding in these cases may resemble that seen in chronic mastoiditis, but this condition is usually bilateral, and the shadow of the lateral sinus lies close to that of the auditory canal (Fig. 107).

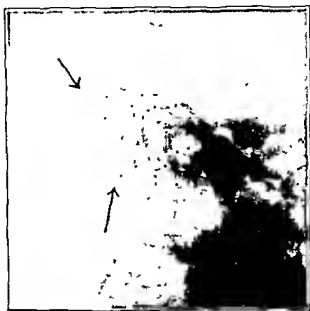


FIG. 109.—Chronic tuberculous mastoid. Note the scalloped lesions characteristic of the disease.

Petrositis.—For the demonstration of petrositis the routine mastoid films should be made, and in addition one anteroposterior with the rays so directed that the petrous portion of the temporal bone lies clear of the base. This view is particularly valuable for details of the petrous tip and the internal auditory canal. Usually an oblique anteroposterior view with the rays directed downward into the posterior fossa, so that the petrous portions overlap the lateral margins of the foramen magnum, should be included, and in some cases a vertical projection of the base will give information not otherwise available.

In petrositis the same changes occur which are seen in the mastoid, and at about the same time. If the bone is diploic a low-grade osteomyelitis develops, with areas of bone destruction appearing on about the tenth day of the infection, accompanied by periosteal reaction on the surface, best seen along the superior margin. Where

there are air-cells present, the course is identical with that in the mastoid, with the same x-ray evidence. Details in this area are more difficult to record but in general, in the early stages, there is a slight general hazy increase in density. Later the apex of the pyramid becomes decalcified and as the infection progresses the trabeculae become blurred, thinned and finally disappear. A chronic infection will cause sclerosis of the surrounding bone, similar to that seen in the mastoid.

Teeth.—The roentgenologist should have a general knowledge of the development, anatomy and pathology of the teeth. An understanding of the course of dentition is helpful not only in the interpretation of dental conditions in children and adults, but also in the determination of the ages of children. The following table from Thoma can be relied upon as a working basis:

Temporary	Calcification begins	Calcification complete	Eruption.	Shed.
Central incisor	.	1½ years	6 to 8 months	7 years
Lateral incisor . .	.	1½ "	1 to 9 "	8 "
Cuepid . .	.	2 "	17 to 18 "	12 "
First molar .	.	20 months	14 to 15 "	10 "
Second molar	.	20 "	18 to 24 "	11 "
Permanent				
Central incisor	1 year	10 years	7 to 8 years	
Lateral incisor	1 "	10 "	7 to 8 "	
Cuepid . .	3 years	12 "	12 "	
First bicuspid .	4 "	12 "	10 "	
Second bicuspid .	5 "	12 "	11 "	
First molar	Before birth	9 to 10 "	6 "	
Second molar	5 years	17 to 18 "	13 "	
Third molar .	9 "	18 to 20 "	18 "	

The importance of good technic in dental roentgenology cannot be too strongly emphasized. It should include adequate exposures with the least possible amount of distortion, preferably from several angles. Ordinarily sixteen to twenty intra-oral films will give an adequate survey of the mouth, but in some cases one or two large extra-oral films will be helpful as a check.

Anomalies of development, irregularity of eruption, and misplaced and unerupted teeth are common, and the diagnosis is obvious. Impaction, particularly in the molar region, is often seen, and the presence of retained temporary teeth is readily recognized.

In adult teeth the roentgen examination is of value in demonstrating fractures below the gum level, and in determining the extent of carious processes, the position and extent of root canal fillings and the results of operative procedures. Pulp stones may

be revealed in the pulp cavities. They are small, round, dense masses, frequently multiple, which form in the pulp chamber of one or more teeth. They have been thought to be the cause of severe neuralgias, but, inasmuch as they are frequently seen without symptoms, their significance is questionable.

The most important pathological conditions with which the roentgenologist has to deal are pyorrhea and alveolar abscesses.



FIG. 110.—Multiple pus pockets involving the roots of the lower molars and bicuspids

Pyorrhea.—Pyorrhea in its early stages gives little roentgen evidence aside from a slight increase in the width of the dark line about the tooth, which represents the periodontal membrane. As the infection continues and the alveolar process becomes involved, the bone retracts from the neck, and finally from the roots of the teeth which are then kept in place only by the fibrous tissue of the gums. As a general rule, when the retraction of the alveolar process involves over half of the root, the tooth is doomed.

Alveolar Abscess.—Alveolar abscess in the acute stage, like osteomyelitis, gives no roentgen evidence of its presence. Very shortly, however, rarefaction appears about the root involved, and, at first, the resulting dark area merges into the structure of the surrounding cancellous bone. As the process becomes more chronic, a limiting wall appears about it, and the picture then becomes one of a definite dark sac attached usually about the apex of the root. This is the



FIG. 111.—1, Pyorrhea pocket about the mesiobuccal root of the left upper first molar, 2, advanced Rigg's disease, with absorption and recession of the alveolus, but without definite pyorrhea pockets; 3, chronic abscesses at apices of palatal and mesiobuccal roots of the left upper first molar; 4, osteomyelitis arising from the roots of the left lower first molar; 5, proliferative, inflammatory granuloma, with central softening at the apex of the right upper second bicuspid; 6, devitalized left lower molar showing caries, root canal fillings and small apical granuloma; 7, impacted right lower third molar, with pus pocket; 8, small pyorrhea pockets about both upper central incisors, and transverse fracture of the left upper incisor.

familiar form of alveolar abscess. Histologically most of them are found to be masses of granulation tissue containing a certain number of bacteria; less frequently there is a definite abscess cavity with a lining membrane. Erosion of the tip of the root extending into this cavity is often seen. In long-standing cases, deposits of new bone laid down about the apex of the root produce bulbous enlargements which may wholly or in part fill the old abscess cavity.



FIG. 112.—Impacted upper canine tooth lying beneath a bridge.

The treatment of such an abscess should depend upon all the evidence, medical and dental, as well as radiological which can be obtained. Not every tooth with an alveolar abscess should be extracted, but each case should be treated upon its individual merits. Abscesses must not be confused with extensions of the antra downward, or pockets in the antra in the region of the upper bicuspids and molars, nor with the submental foramen which frequently overlies the apex of a lower bicuspid. Films of the upper incisors occasionally show the shadow of the nostril overlying a root which simulates an abscess. On the other hand, small abscesses arising from lateral margins of the root and overlapped by the image of the tooth may be overlooked entirely.

Cysts.—Cysts are fairly common in the jaw. There are two forms: root cyst and dentigerous cyst. The former appears as a large rounded area of rarefaction in the jaw, usually attached to or partially enclosing one or more tooth roots and showing little or no evidence of trabeculation. It may be multiple. Dentigerous cysts have a similar appearance except that they develop from a buried tooth bud and generally contain teeth or portions of them. The bony structure of the jaws may be subject to any of the diseases which affect the rest of the skeleton. Osteomyelitis is fairly common and shows the same irregular destruction and proliferation



FIG. 113.—Simple cyst of the jaw



FIG. 114.—Adamantinoma

seen elsewhere. A localized osteomyelitis in the anterior portion of the mandible may extend into the inferior dental canal and drain through the foramen in the ascending ramus into the soft tissues of the cheek, producing an inflammatory mass in the region of the parotid gland. A particular sort of osteomyelitis occurs with phosphorus poisoning, the bone becomes increased in density and thickness as a result of new bone production which is followed later by suppuration and necrosis represented by irregular rarefaction. A lesion of the jaw has occurred in workers using radium paint. It is seen as a widespread dry necrosis, without sequestra. Syphilis occurs occasionally in the form of an irregular mottling of the bone due to extensive spotted rarefaction.

Almost any benign or malignant tumor may occur in the jaw. The most common forms are cysts, giant-cell tumors, osteogenic sarcoma, carcinoma. Their appearance is identical with that of similar growths in other flat bones. In addition, the jaw is the seat of a tumor peculiar to it, the odontoma, which is a dense mass made up of various tooth tissues and may be attached to a tooth or be composed of several teeth fused together. Sometimes they take the form of undefined masses of considerable density, which continue to grow, and develop into large deforming tumors. Adamantinomas are slowly growing masses which may or may not contain calcified material. They usually show multiple irregular small cysts within their structure. They expand the alveolar process carrying a thin bony shell ahead of them. The solid forms of the tumor are rare; they usually occur in the upper jaw and require two to three years for their development. The much more common, cystic form generally appears in the lower jaw and may take ten or fifteen years to develop. These tumors do not metastasize but they tend to develop local implants after operative removal.

Salivary calculi must be mentioned in any consideration of the teeth. They cast dense round or oval shadows seen in the position of the salivary glands or ducts. When projected upon the mandible in oblique views they must not be mistaken for areas of density in the bone. The outlines of the ducts and their branches in the salivary glands may be demonstrated by filling them with lipiodol. This is a useful procedure where stones are suspected but are not demonstrated on routine films.

The shadows of calcified cervical glands often appear in films taken of the teeth. They are spotted, mulberry-like shadows, characteristic of calcified glands anywhere. The tip of an unusually long

styloid process may be projected upon the upper molar region and be mistaken for a tooth root, or a supernumerary tooth.

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CHAPTER VI.

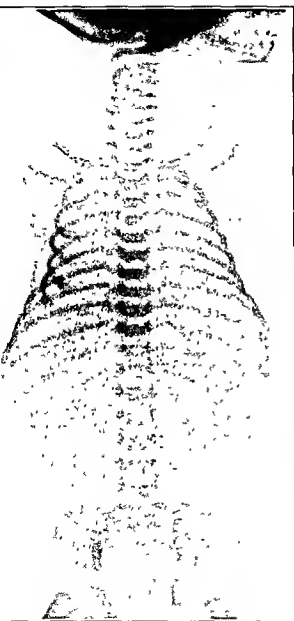
THE SPINE.

FROM the roentgen-ray viewpoint the spine consists of a series of bodies of cancellous bone structure increasing in size from above downward, separated by transparent cartilaginous discs, and presenting posteriorly a more or less confused and overlapping mass of pedicles, laminae, articular and spinous processes. An antero-posterior view shows the bodies arranged in a straight line, the intervertebral discs and the articulations seen well in some regions and poorly, or not at all in others, according to the angle of the incident rays. The laminae and spinous processes overlap them, the latter following a more or less straight alignment uniformly spaced.

In the lateral view the bodies follow a smooth sinuous line. There is a forward curve in the lower cervical spine, depending in shape upon the position of the head, a pronounced backward curve in the thoracic region (most marked usually in the upper half) which blends gradually into the forward projection of the lumbar spine and ends with the decided backward course of the body of the sacrum and the anterior return of the lower sacral and coccygeal segments.

The arcs of these curves, like everything else in the spine, are subject to great variation depending upon the type of individual, sex, weight, occupation and age, and no great emphasis should be placed upon them with the following exceptions: First, where there are abrupt changes from the normal alignment limited to two or three bodies; such a condition occurs as a result of trauma, infection, arthritis or malignancy and should prompt most careful investigation of the affected area. Second, where the normal curve is reversed; *e. g.*, in the lower cervical spine in cases of arthritis, where the convexity of the line of the bodies is backward.

The angle between the lumbar and sacral spine is extremely variable. In childhood it is rather flat; in normal adults it averages 120 degrees. A line drawn through the center of the disc between the last lumbar and first sacral bodies forms an angle of about 30 degrees with the horizontal plane. Variations from this average are seen in both directions.



. 115 —Spine of new-born infant. Anteroposterior view.

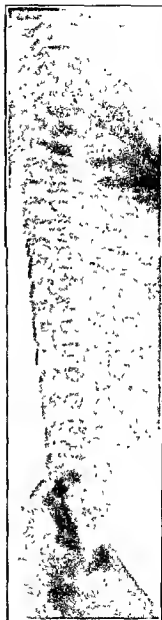


FIG 116 —Lateral view.

Technic.—The position of the tube with reference to the patient in spinal examination is of considerable importance. In dealing with a curved structure, a source of diverging rays and a flat recording surface, it is necessary to emphasize the importance of always having the target of the tube as near as possible to the center of curvature of the arc under examination. It is impossible to secure



FIG 117.—Lateral view of normal adult lumbo-sacral region.

accurate projections of more than one vertebra at a time when the source of the rays is relatively close to the convex side of the curve, as is the case when taking a well-rounded lumbar spine from the front. Theoretically, the best views of the cervical and lumbar *bodies* should be secured with the tube behind the patient at a level corresponding as nearly as may be with the center of curvature of these regions. Practically this may be done with profit in thin

individuals. In anteroposterior views, successive films of small areas taken with the incident rays directed along radii of the arc should be the rule. Probably from neglect of this simple matter, more errors of interpretation have occurred at the lumbo-sacral junction than in any other portion of the skeleton. Fortunately lateral views of all parts of the column are now available and are a great help in checking the findings of the anteroposterior views. Here again the choice of sides and the level of the target should depend upon the amount of lateral curvature of the bodies as the patient lies upon the film, the effort being always to make the divergent rays pass clearly through as many intervertebral discs as possible.

Development and Epiphyses.—The process of ossification begins in the second month of fetal life. Each vertebra presents at least five centers of ossification, one for the body, two for the neural arch and two for the transverse processes. The center for the body may develop from two nuclei, one for each lateral half. Wedge-shaped and extra-half bodies are the result of asymmetrical growth of such multiple centers, or of the absence of one. Bodies of the vertebrae of infants often show partial vertical divisions due to incomplete fusion of multiple ossification centers; many children up to the time of puberty show, in the lateral view, thin horizontal zones of rarefaction extending backward from the middle of the anterior margin of the body, due to remnants of the bloodvessels of early fetal life.

The centers for the neural arches fuse at the sixth to the eighteenth month after birth. Union begins at the tenth thoracic vertebra, and extends up and down the column from this level. The fifth lumbar vertebra and the sacrum close at about two years.

Small accessory centers appear later for the tubercles on the articular processes, and for the tips of the transverse and spinous processes. From the twelfth to the fifteenth year small plates appear at the corners of the bodies first seen in the lower thoracic region; they are united to the bodies by the twenty-fifth year, but in some individuals one or more may persist into adult life. They have been mistaken for fractures. The fifth lumbar vertebra may have one center on each side from which is developed the pedicle, transverse and superior articular processes; and a second center for the lamina, inferior articular process, and lateral half of the spinous processes.

Failure of union of these nuclei may give five lines of cleavage

first, through the spinous process; second and third, between spinous processes and articular processes on the two sides; and fourth and fifth, between articular processes and the body. Such breaks in the neural arch may last through adult life and many of them have been erroneously considered fractures. They are of great importance in connection with the production of spondylolisthesis.



FIG. 118.—Extra half vertebra

Bodies.—Inasmuch as they are composed almost entirely of cancellous bone, vertebral bodies are involved in the same disease processes as spongy bone elsewhere, and they react in the same way to trauma and disease. In children they are affected by the same diseases, and at the same ages, as the epiphyses of the long bones. In adults, the mechanism and healing of fractures and the type and course of malignancies are identical with those in all cancellous bones.

The normal body is smooth upon its lateral margins. Its superior and inferior surfaces may be somewhat irregular and are often concave. Where exaggerated curvatures are present, normal bodies assume a wedge shape. This is seen in the thoracic region where the anterior portions of several adjacent bodies may be considerably compressed; and the fifth lumbar body is almost uniformly thicker anteriorly than posteriorly.

In general, individuals of heavy build have large, broad vertebral bodies, while persons of slight habitus have narrow, high ones.

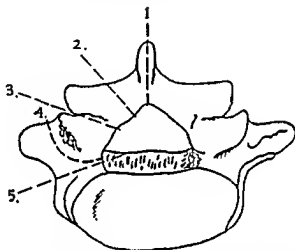


FIG. 119.—Showing five planes along which failure of union may occur (After Willis)

Erosion of the bodies results from pressure exerted by neighboring tumors. The most common example is the crescentic defects produced in the thoracic or lumbar bodies by aneurisms of the aorta. The discs are relatively resistant while the affected bodies are deeply scalloped.

Discs.—The intervertebral discs being cartilaginous are, of course, transparent, but the spaces occupied by them are easily demonstrable with proper technic. They may be absent in congenital anomalies, of which a common example is the fusion of the atlas and axis, or two or three adjacent bodies in any portion of the column. They may disappear as a result of infection, with bony union of the adjacent bodies; this is seen after typhoid lesions and in healed mild tuberculosis. The discs are thinned in old age, also as a result of chronic arthritis, and in early stages of infection in their vicinity.

Frequently the earliest evidence of a beginning tuberculosis is a narrowing of the adjoining intervertebral space.

Thin plates of calcification are sometimes seen within discs but are without clinical significance.



FIG. 120 — Multiple anomalies. Long twelfth rib on the left side, fused second and third, lumbar vertebrae, sacralized sixth lumbar body.

The discs are likely to be preserved following trauma, and in luetic lesions of the spine. Increase in thickness is practically always a local compensatory reaction to an increased angulation between bodies. In the sacrum, portions of the intervertebral discs often persist throughout life.

The disc is composed of the oval fluid nucleus pulposus in an elastic capsule surrounded by the complicated fiber pattern of the *annulus fibrosus*, which is *strongly attached to the borders of the adjacent vertebræ*. This center is elastic and acts as a coiled spring which tends to expand whenever its confining structures are weakened. When the disc is ruptured the nucleus may be dislocated in any direction. It will then produce a notch in one or both of the adjacent vertebræ, or a localized expansion of the capsule may occur in any direction, forward, backward or sideways. When the vertebral body is generally weakened, as in osteomalacia, the elastic nucleus produces a fusiform expansion of the disc, with *corresponding concavities on the vertebral bodies*.

Articulations.—The plane of the articulations in the cervical and thoracic regions is roughly transverse and, when seen in the lateral view, inclined forward at the top so that the articular processes overlap each other from above downward like shingles on a roof. In a well projected cervical spine most of the articulations are seen in the lateral view. For the demonstration of those between the base of the skull and the first and second cervical vertebræ an anteroposterior exposure may be taken through the mouth with the tip of the upper incisors at the level of the base of the skull. In individuals with thin antral walls, excellent views of the articulations between the occiput, first and second cervical vertebræ, can be obtained by projecting the base of the skull across the tops of the antra in an anteroposterior view.

A vertical projection of the base of the skull, with the patient's head tilted well back against a film, and the incident ray coming in through the larynx, gives a good view of the body and transverse processes of the first cervical vertebra and the relation of the body of the first to the odontoid process. This position is especially valuable in dislocations of the first upon the second.

Owing to the confused shadows of ribs and scapulae, the joints in the thoracic region are often not well outlined.

At the junction between the twelfth thoracic and first lumbar vertebræ, the articulations are rotated to a position nearly sagittal, and this is true for the remainder of the lumbar spine. The articulations in the lumbar area are well shown by oblique views, with the patient turned halfway between the supine and lateral positions.

There is the greatest variation at the lumbo-sacral junction. Both joints may be transverse, which gives the most stable back. Both may be sagittal, which throws a great strain upon the liga-

mentous structures; or one may be transverse and the other sagittal. In the latter case the transverse joint cannot, of course, be made out upon an anteroposterior film; only the rounded and sometimes rather roughened outline of the articular process appears, and it has been mistaken for inflammatory or hypertrophic change in the joint.



FIG. 121.—*Spina bifida*—Absence of spinous processes in the lower lumbar and sacral regions.

Spinous Processes.—All the spinous processes are evident in the anteroposterior view, and their alignment and spacing are of considerable importance.

In the normal spine there are always slight deviations of the tips of these processes from an exactly straight line. Variations on the

part of individual processes to the extent of 5 to 6 mm. from the midline are of no consequence and should be disregarded.

Abrupt changes in vertical alignment at a given level, producing a definite angulation in a line through the processes above and below it, or a break in the line so that the processes above are displaced laterally upon those below, usually indicate a serious lesion of the bodies or articular processes, and further examinations should be made to check this finding.

Abnormally wide intervals between neighboring processes are most often due to rupture of the interspinous ligament accompanying dislocation of bodies, and always call for a lateral survey of this area.

Failure of union of the two halves of the spinous processes is frequently seen in the lower lumbar region, at times in the cervico-dorsal, and more rarely in the dorso-lumbar areas. This condition may be mistaken for fracture. When it is marked, it leads to weakening of the neural arch and predisposes to ligamentous strains, particularly at the lumbo-sacral junction. Extreme examples are seen in spina bifida.

Small separate ossification centers for the tips of the spinous processes may fail to unite with the vertebræ.

Transverse Processes.—The transverse processes of the cervical region are small except on the sixth and seventh vertebræ. Those of the seventh may be large and long, simulating short cervical ribs. They are rarely of any importance clinically. Those in the lumbar region are long, variable in size, and may be fractured in severe injuries of this area.

Small accessory ribs are seen at times upon the first lumbar vertebra; these must not be mistaken for fractures of transverse processes. Ordinarily the smooth articular surface between the rib and pedicle will prevent errors of this sort.

Wide transverse processes on the fifth lumbar may impinge upon the top of the sacrum, or upon the wings of the ilia, causing symptoms by pressure, or by ligamentous strain due to the abnormal leverage of the process. These large lateral masses may have articulations upon the opposing surfaces.

The ilio-lumbar ligaments between the crests of the ilia and the transverse processes of the fifth lumbar vertebra may become calcified and cause local pain.

Anomalies.—As has been indicated, the vertebral column is subject to marked variation in development. The points where these

variations are most likely to be found are where transitions occur: cervico-dorsal, dorso-lumbar and lumbo-sacral junctions.

In addition to the variations already discussed there may be striking abnormalities in the development of bodies and ribs, and when one anomaly is found there will usually be others present; *e. g.*, failure of union of spinous processes and extra ribs, fusion of ribs, and extra bodies or portions of bodies. Perhaps the most frequent variation in bodies is the occurrence of an extra vertebra. This usually happens in the lumbar and sacral regions and is without clinical significance.

Extra half bodies are seen at times, and if in the thoracic region they are accompanied by a corresponding extra rib on the same side. Such variations have been called fractures, and have brought compensation to their owners following industrial accidents. These anomalous bodies are of normal structure and smooth in outline, and should be readily differentiated from the changes due to trauma or infection (Fig. 118).

Small triangular accessory ossification centers occasionally persist on the margins of the bodies and at the tips of the inferior articular processes in the lumbar region. They are often mistaken for fractures, particularly in industrial accident cases where the patient has received an injury in this area. One must remember that these separate centers are common while fractures are rare, and that the adjacent edges of the bone are smooth and rounded and show a fairly good cortex when an anomaly is present, while the edges of a fracture are more ragged and usually without a cortex.

The most important variations are found at the lumbo-sacral junction; they are of great consequence because of the strain thrown upon this region in transmitting the weight of the body to the pelvis. Variations of some sort are found here in from 10 to 20 per cent of all individuals.

The usual findings are:

1. Changes in lumbo-sacral angle, which may be very flat or markedly increased.
2. Extra lumbar or sacral bodies.
3. Wide lateral masses upon the last lumbar vertebra which show all gradations from slight enlargement through those articulating with or impinging upon sacrum and ilium, to complete fusion of one side with the sacrum (partial sacralization).
4. Rotation of the planes of the articular processes.
5. Imperfect development of articular processes.

6. Breaks in the neural arch of the last lumbar vertebra (unilateral lesions of this type are more common on the right side).

Any of these may cause symptoms of varying intensity according to their degree, and the size, occupation, muscular development and traumatic hazards of the individual. People carrying such anomalies are more liable than normal persons to increased disability from a given cause, because of the additional ligamentous strain which is present and the imperfect mechanical support afforded.

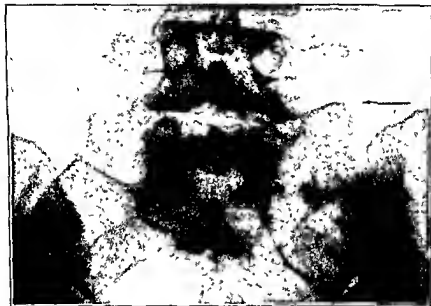


FIG. 122.—Sacralized transverse process of the fifth lumbar vertebra upon the left side, indicated by the arrow.

Spondylolisthesis.—Spondylolisthesis, or forward displacement of the lower lumbar vertebræ, may develop as the result of extreme violence which ruptures attachments and lifts the lumbar articular processes over those on the sacrum, or fractures them. More commonly it is seen as a result of breaks in the neural arch in the region of the articular processes which permit gradual forward displacement of the affected body. Where this condition has existed for any length of time one sees beveling of the superior margin of the sacrum and inferior edge of the fifth lumbar vertebra, usually accompanied by hypertrophic changes. In the anteroposterior views the transverse processes of the fifth lumbar vertebra tend to overlap

the top of the sacrum and the overhanging edge of the fifth body may be seen as a crescent across the upper sacrum. There usually is a rather wide separation between the spinous processes of the last lumbar and first sacral segments. Where there is a defect in the laminae a definite break suggesting a fracture line with hypertrophic changes about it may be seen, or merely an indefinite inter-



FIG. 123.—Anomaly of the neural arch of the fifth lumbar vertebra which shows multiple breaks in continuity.

ruption at the outer extremity of the lamina which fails to blend smoothly into the pedicle. Films of the highest technical quality and lateral views are essential.

The fourth lumbar vertebra is occasionally displaced forward upon the fifth in older individuals, without a break in the neural arch. This condition is due to erosion of the articular processes or to the presence of a congenitally long pedicle.

TRAUMA.

Soft Tissues.—Acute injuries to the supporting soft tissues about the vertebrae are not directly demonstrable. Their presence is



FIG. 124.—Compression fracture of the body of the first lumbar vertebra; lateral view. Very slight clinical evidence of the lesion.

assumed where the *normal relations of bony structures* are disturbed. When ligamentous lesions heal, hypertrophic spurs and bridges usually develop locally on the margins of the affected bones.

Fractures.—Fractures of vertebral bodies result from considerable violence, such as falls or heavy crushing injuries, particularly in cases where the patient is strongly flexed. The line of fracture is seldom definite, the diagnosis resting upon deformity in outline and alterations in cancellous structure. Callus rarely develops.

There are two general types: First, compression fractures which may vary from a slight check in the anterior or lateral margins of a body (similar to a greenstick fracture in a child's long bone), to a complete collapse of a portion of a body. The milder forms of this injury commonly show little objective evidence of the lesion aside from persistent local tenderness. X-ray examination may be negative in the acute stages of such an injury while later films may show a partial collapse of the injured vertebral body. Second, comminuted fractures, the result of more severe trauma in which the vertebra is extensively shattered either by direct violence or by the impaction of another body into it. This second form, as a rule, gives unmistakable clinical evidence of its presence; but cases have been reported in which lesions of this type have gone unrecognized for months or years until proper roentgen-ray studies revealed them. Acute fractures of this sort may be completely reduced by hyperextension and practically normal outlines restored.

Injuries most frequently occur at the dorso-lumbar level, next in the mid-dorsal region, and third, at the level of the fourth to the sixth cervical bodies. Fracture of the fifth lumbar vertebra is extremely rare.

The differentiation between this condition and the destruction by an acute infectious process (often accompanied by the impaction of one body into another), may be a matter of some difficulty. In the majority of cases the traumatic lesions will show a substantial portion of the intervening disc still present, while in the infectious type the cartilage commonly disappears. Infectious processes of this extent are usually accompanied by the formation of perivertebral abscess.

Fractures of the neural arch including the articular processes is a more disabling injury, on account of the involvement of nerves and interference with motion. The direct demonstration of these breaks upon a film may be a matter of great difficulty, particularly in the thoracic region. Indirect evidence may be furnished by the presence of callus formation. Unlike the bodies, these portions of the spine readily form callus which becomes calcified after the usual interval of a few weeks. Slight degrees of lateral rotation of one body

upon another, abrupt changes in the alignment of the spinous processes and varying degrees of dislocation may call attention to a fracture which itself might never be clearly visible.

Transverse Processes.—Fractures of these structures are usually multiple, several adjacent vertebrae being affected. Single processes may be broken by local injuries such as blows from sharp implements. Usually a small amount of callus is to be expected, but fibrous union may develop.

Care should be taken not to diagnose fractures from the black lines formed by muscle shadows crossing these processes. Such lines are smooth and straight and upon close inspection will be found to extend beyond the margins of the bone.



FIG. 125.—Fracture of the fifth cervical vertebra with forward dislocation of the fourth.

Dislocations.—In cases of spinal injury it is essential to have films in two planes, at right angles and often oblique views as well.

Frequently, slight degrees of dislocation of the cervical vertebrae, which are unrecognized upon anteroposterior films, are perfectly obvious in the lateral view.

Or the anteroposterior view may show only an increased distance between the spinous processes of the affected vertebrae. The lateral film, in addition to the interspinous separation, reveals the extent of injury to the bodies and the amount of over-riding. As a rule, the upper bodies slip forward upon the lower.

Displacement of the skull upon the first cervical vertebra is commonly fatal, and these lesions are rarely seen by the roentgenologist. The atlas may be rotated laterally upon both skull and axis in children without causing permanent disability, but the usual dislocation at this level is accompanied by fracture of the odontoid process. For the recognition of this condition, films through the widely opened mouth as well as accurate lateral views are necessary. In the normal individual, a true lateral view will show the anterior margins of the bodies of the second and third cervical vertebrae lying upon an approximately straight line, and the odontoid process inclined somewhat backward. The posterior margin of the body of the second cervical vertebra continues smoothly without a break into the outline of the odontoid. The odontoid process arises from a separate center of ossification, which may fail to unite with the body in some cases.

Spondylolisthesis is best recognized in lateral views. The mechanism of its production has already been discussed. It should not be forgotten that where a unilateral displacement occurs the spinous process is shifted toward the affected side, unless there has been a break in the lamina.

"Sacro-iliac slips" have long been a subject of animated discussion. Clinicians and surgeons tend to read more pathology into these joints than experienced roentgenologists are willing to admit. Slight variations in the width of the joint space and the alignment of the adjacent bone margins are so common in individuals who are symptom-free that it is extremely difficult, if not impossible, to find any roentgen-ray confirmation of the common clinical diagnosis of relaxation, strain or slip. Difference in the levels of the upper margins of the pubic bones at the symphysis, which has been urged as an index of sacro-iliac rotation, has proved to be of little value.

A disturbance occurs in the sacro-iliac joints in adolescents of fifteen to seventeen years, in which the joint margins become hazy,

with areas of increased density. It is due to an affection of the epiphyses which are present at this time on the margins of the sacrum, and is similar to osteochondritis elsewhere in the spine.

Real dislocations of the sacro-iliac joints do occur, but only as the result of falls from a great height, or from severe crushing injuries, and they are usually associated with fractures elsewhere in the pelvic ring.

The coccyx may be dislocated forward upon the sacrum by a fall or a blow. Lateral views are necessary to confirm the diagnosis.

Scoliosis.—As a result of the failure of supporting structures or more rarely because of asymmetrical development of the vertebrae, lateral curvatures of various degrees are seen. The slight ones are usually postural and no permanent change in the shape of the bodies is present. The severe forms are caused by anatomical variations in the vertebrae, or by paralyses; and they usually show one or more wedge-shaped vertebral bodies. A survey of the entire spine in such cases will at times give a clue to the causative factor.

INFECTIONS.

Tuberculosis.—Tuberculosis is the common infection involving the spine. It most frequently begins between the ages of two and five years. Approximately 60 per cent of the cases occur in the thoracic region, 20 per cent in the lumbar and sacral portions, 15 per cent at the dorso-lumbar junction and 5 per cent in the cervical region. The picture is one of irregular destruction of one or more vertebral bodies followed by their collapse and the disappearance of the affected intervertebral discs; in a few rare cases the disc is not destroyed. A fusiform shadow about the diseased area, usually best seen in the anteroposterior film, results from the development of a perivertebral abscess which may extend for a considerable distance up and down the column. If drainage is not established such abscesses may persist for years and gradually become calcified as they heal. In the acute stages of the process in adults the lesions in the bodies may be invisible, but thinning of the intervertebral discs adjoining the infected body occurs early. This diminution in the intervertebral space usually involves the entire disc uniformly and calls for careful observation of the suspected area.

Well established cases may show one body impacted into another, or several bodies considerably eroded; and although the intervertebral cartilages may be destroyed, the articular processes will

preserve a certain amount of separation between the remnants of the bodies.

Healing of the process may occur at any stage, with gradual restoration of normal density and structure in the fragments of bone which remain unaffected, and the appearance of calcification in the tissues about them. The angulation of the spine persists. It is partly compensated for by thickening of the anterior portions of the intervertebral discs above and below the lesion.



FIG. 126.—Tuberculosis of the thoracic spine in an adult.

Tuberculosis of the sacro-iliac joint is rare. When it does occur it is usually part of a generalized process and is more often seen in adults than in children.

It produces an increase in the width of the joint space and a ragged irregular mottled appearance throughout the joint. The adjacent bone may be increased in density.

Typhoid.—This lesion appears in the form of localized areas of rarefaction near the corners of vertebral bodies, with local thinning of the adjacent disc and the subsequent development of a heavy bony bridge about the focus and disc, resulting in complete obliteration of the cartilage and fusion of the adjoining vertebrae. Differentiation of this condition, from congenital fusion depends upon the clinical history, and evidence of other anomalies in the spine.



FIG. 127.—Lateral view of the same patient as in Fig 126.

Lues.—Lues seldom involves the spine. When it does occur it takes the form of extensive coarse proliferative lesions involving several bodies; there may also be some evidence of bone destruction. The discs are usually preserved. Irregular destructive lesions in the articular and spinous processes have been seen resembling those in the ends of long bones. Charcot joints may occur in the cervical

or lumbar region. The changes are those seen elsewhere in this disease. increase in the density of the affected bodies, and large, irregular bony masses in the soft tissues about them.



FIG. 128.—Tuberculosis of the spine showing calcification in a small psoas abscess

Osteomyelitis.—When osteomyelitis occurs in the spine, the process is similar to that seen in other bones of the same type, causing irregular rarefaction and new bone formation about the diseased

area. The clinical picture aids in the diagnosis as the process is more acute in pyogenic infections than in those previously mentioned, and the constitutional reaction is more severe. Chronic lesions such as those of actinomycosis or blastomycosis produce irregular areas of destruction, usually in several bodies which, how-



FIG. 129.—Tuberculosis of the spine showing little activity after several years of treatment. Note the sharp edges of the three bodies chiefly involved. Areas of activity still present in the body beneath them at A.

ever, do not collapse. Chronic perivertebral abscesses accompany these lesions and the responsible organism may be isolated in the discharge from their sinuses.

Arthritis.—The common change due to arthritis in the spine is the development of hypertrophic fringes on the margins of the

bodies. These may be no more than slight sharpening of the edges of the vertebræ or, in old cases, large hooks which practically enclose the intervertebral space. This condition is more common in muscular, heavy individuals, and may be due to chronic infection, or long-continued strain, or both. Localized hypertrophic changes involving only one or two vertebræ are usually the result of an injury. Similar changes occur about the articulations but



FIG. 130.—Typhoid spine. Film taken two months after the onset of pain in the back and three months after the beginning of the illness. It shows narrowing of the intervertebral space and areas of bone destruction in the posterior part of the bodies. Film six months later showed fusion of the anterior margins of the bodies and clean-cut outlines posteriorly.

are not particularly evident in ordinary cases. These smaller changes, particularly those about nerve canals and articulations, are a common cause of chronic back pain and are probably of considerably greater importance to the patient than the larger fringes upon the bodies.

The lower lumbar nerves pass out behind the intervertebral discs, the posterior and lateral surfaces of the vertebral bodies and in front of the articular processes. This course renders the nerves

vulnerable to irritation or infection either in the discs or the articulations. With the disappearance of a disc from any cause, there is necessarily some over-riding of the articular facets, which reduces



FIG. 131.—Hypertrophic changes on lumbar vertebrae.

the diameter of the nerve channel. This is particularly true of the lumbo-sacral joint.

It must not be forgotten that such changes in the lower cervical vertebrae are a frequent cause of symptoms in the arms.

In persons over sixty years of age, who have had long-standing arthritis, the backward curve of the upper thoracic spine may be greatly increased due to gradual compression of the anterior portions of these bodies. A number of adjoining bodies are involved, and their structure shows a considerable degree of rarefaction. These points are important in the differentiation of this condition from compression fracture which does not affect multiple bodies uniformly.



FIG. 132.—Ankylosing type of arthritis. Note the complete fusion of the vertebrae and disappearance of the sacro-iliac joints

Any type of infection may develop in the articulations of the spine and usually there is very little evidence upon the film by which to identify the invader. The picture is that of localized destruction of the articular surfaces, thinning of joint spaces and, in the healing stage, various degrees of new bone formation.

The Marie-Strumpel type is a severe and disabling form of arthritis

sometimes seen in young individuals, in which there is a disappearance of the articulations throughout the spine with subsequent complete ankylosis. Similar changes in the hips and shoulders may accompany the spinal lesions. It usually begins in the sacro-iliac joints and moves progressively upward. The articulations are first affected and later bony spurs appear about the intervertebral spaces. After several years the spine is completely ankylosed. The upper cervical vertebrae are usually spared.

TUMORS.

Any tumor developing in cancellous bone may be found in the spine. Primary tumors are rare, metastatic lesions fairly common.

Angioma causes a coarsening of the structure of the affected body, the trabeculae are widely spaced and the vertical ones are increased in size and density. The bodies are not enlarged. Usually the process is limited to one body, but several adjacent bodies may be affected. The disease is more common in older individuals.

Giant-cell tumors show their characteristic trabeculation. They are prone to extend into the processes, and even to involve adjacent bodies.

Any form of primary osteogenic tumor may attack the vertebrae. The appearance varies from complete localized destruction of the affected bone by the rapidly developing growth in the slowly growing fibrous type which is indistinguishable from metastatic carcinoma. The early lesions are apt to involve one margin, or one side, of a body which is progressively destroyed. The body does not collapse unless the growth is unusually soft, the tumor mass carrying the load—in some cases—for a period of years.

Malignant lymphoma, when it involves the vertebrae, causes a haziness in outline and a mottled appearance which is not characteristic, or there may be extensive destruction with collapse of a body. In some cases there is direct extension of the process from adjacent lymph nodes.

The common forms of carcinoma produce a mottled rarefaction which is quite definite, but extensive involvement of several bodies may be present without recognizable evidence of the disease on good films. Other parts of the skeleton are usually affected and the primary lesion may be discoverable. As a rule several bodies are involved.

Certain slowly growing *carcinomata*, most of them metastatic from the prostate, breast or thyroid, give a striking picture owing to the marked bony reaction they evoke. The spine, ribs and pelvis are greatly increased in density, and somewhat mottled. Cases of this type may live for many years.



FIG. 133.—Angioma of a thoracic vertebra.

Myeloma produces rarefied lesions with multiple trabeculations running through them somewhat resembling giant-cell tumors. More than one vertebra is usually involved and there are associated lesions in other bones, notably ribs, sternum and skull. Single lesions may occur (Fig. 134). The tumors are soft, and gradual compression of the affected bodies is to be expected. Radiation sometimes gives marked relief of pain.

Hypernephroma may occur as a single destructive lesion and be confused with a primary tumor. It has no distinguishing characteristics.

Osteochondritis.—Calve has described a condition in which vertebral bodies in children showed marked flattening and irregularly increased density resembling the changes seen in the tarsal scaphoid, the head of the femur and other cancellous areas. The process pursues a *chronic course with spontaneous healing*. The adjoining discs are thickened rather than thinned.



FIG. 134.—Tumor of second lumbar vertebra diagnosed benign giant-cell tumor and treated with irradiation in 1925. Patient was operated upon December 15, 1930; specimen removed at this time was diagnosed myeloma. There was no other bone lesion.

In certain dwarfs with irregular and delayed development of the epiphyses of the long bones, the vertebral bodies have showed the same erratic growth as the epiphyses, resulting in marked deformities of outline and structure.

Kummel and Verneuil have described a gradual softening of vertebral bodies following trauma. Vertebrae showing no immediate evidence of injury have slowly lost their density and undergone a gradually progressive collapse.

Spinal Cord Tumors.—Tumors of the spinal cord may produce localized erosion of the bone overlying them, but in general no demonstration of such lesions is to be expected. Narrowing or disappearance of a pedicle is one of the first signs of pressure and should always be looked for. The introduction of iodized oil into the subarachnoid space following spinal puncture is a reliable method of localizing such growths.



FIG. 135.—Rapidly growing metastatic carcinoma.

Backward projection of an intervertebral disc into the neural canal has been found in some cases as a cause of persistent pain and disability. The lumbar region is a common site, and the symptoms may suggest either sacroiliac strain or cord tumor. The lesion is best demonstrated by fluoroscopic observation of the opaque oil as

it flows over the suspected area and by the taking of "aimed" films in the position which most clearly shows the deformity.

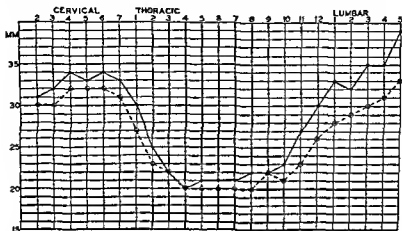


FIG. 136 —Elsberg and Dyle's chart of the normal measurements between pedicles at the various levels of the spine. Extreme upper limits, solid lines, usual upper limits broken lines. Measurements greater than these suggest the possibility of spinal cord tumor and call for a careful neurological examination, particularly if they are associated with compression of the pedicles.

Neurofibroma may extend out along one or more nerve roots, erode or separate the surrounding pedicles or ribs and develop a large rounded mass within the chest or abdomen.

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CHAPTER VII.

JOINTS, TENDONS AND BURSÆ.

THE JOINTS.

Trauma.—Injuries to joints may be accompanied by soft tissue swelling, separation of ligamentous attachments, dislocations or fractures. If important ligaments have been torn abnormal mobility may be present.

Loosening or separation of the lateral ligaments of the knee may be demonstrated by two antero-posterior films, one made with inward pressure on the lower end of the femur combined with a lateral pull on the ankle, so that the internal lateral ligament is put under tension, and a second film made with outward pressure on the lower end of the femur and an inward pull on the ankle, to test the external lateral ligament.

Similarly separation of the crucial ligaments may be looked for in lateral views made with the tibia pressed forward and backward upon the femur.

When a tendinous insertion is pulled loose a small flake of bone is usually detached with it and in the process of repair a bony spur may form at the site of the separation, or a fibrous union occur with a small rounded osteophyte remaining as evidence of the injury.

Arthritis.—There is as yet no really satisfactory classification of joint diseases. It must be insisted that no hard-and-fast adherence to the general types described below is possible. Atypical joints and those which fall under more than one heading are often observed. In the study of a pathological joint, the following features should be carefully noted: (1) Periarticular swelling in the soft parts, (2) effusion in the joint, (3) erosion of cartilage as evidenced by diminution of the joint space, (4) changes in density of the bone, (5) outgrowths of new bone formation, (6) the joints involved and (7) age and sex of the patient.

Hypertrophic arthritis is the most common form. It occurs in individuals over forty years of age, more often men of a sthenic type, and is slowly progressive. It is caused by mechanical strain, interference with the circulation of the joint, infections or intoxications. A localized form frequently develops about the margins

of vertebrae which have been injured. Its characteristic feature is the presence of spurs, or lipping, on the margins of articular surfaces and vertebral bodies. These outgrowths are dense with sharp edges, and in some cases cause fixation of a joint by interlocking or fusion. There is no effusion in the joint unless it has been recently injured. There is usually no narrowing of the joint space and no decalcification of adjacent bone. It may attack any joint, usually the larger ones, and is very common in the spine. These joint changes may exist for a considerable length of time without giving definite symptoms, but they are apparently points of lowered resistance for, after injury, they may be the seat of acute painful reactions which are entirely out of proportion to the injury and would not have occurred in a normal joint. This condition is continually being encountered in industrial accident work. (See Fig. 131.)

Atrophic Arthritis.—Atrophic arthritis is more common in women between the ages of twenty and fifty. It begins with periarticular swelling followed by gradual loss of articular cartilage, shown by narrowing of the joint space, and is accompanied by severe atrophy of the soft parts, and decalcification of bone. There is no tendency to new bone or spur formation. The hands and feet are usually affected first, and later, the knees, elbows and shoulders may be involved. The process extends over a period of years, ending typically in complete ankylosis.

Gout.—Gout is less common but, like the first type, occurs after forty, more frequently in men than in women. In a typical case it presents periarticular swelling and characteristic punched-out areas in the hoes at the margins of the articular surfaces. These holes are sharply cut and vary from one to several millimeters in diameter, in severe cases causing complete destruction of an articular end of a bone. There is little effusion in the joint, erosion of the cartilages occurs only in the late severe cases, and there is no decalcification. Usually slight hypertrophic spurs are present. It ordinarily occurs in the phalangeal joints of the hands and feet, but may affect the carpus or tarsus, and in rare cases a large joint, such as the knee. In the early stages before the punched-out areas become evident it may be mistaken for a hypertrophic arthritis. If is, of course, accompanied by other clinical evidence of the disease.

Charcot Joints.—Charcot joints are due to trophic disturbances, usually associated with tabes dorsalis or syringomyelia. When of tabetic origin, the weight-bearing joints are affected while in syringomyelia the upper extremities are more commonly involved.

There is great swelling of the soft parts, destruction of articular surfaces amounting to complete disorganization, and large irregular masses of calcified material are seen scattered throughout the relaxed joint capsule. The bone is more likely to be increased in density than rarefied. Conditions which may be confused with it are: (1) Loose bodies in joints, in which case the calcified masses are small, dense and few in number, and the joint surfaces are not



FIG. 137.—Gout.

disturbed except that the point of origin of a fragment may be evident in a chipped-off area on the articular surface; or (2) calcified hematوماتa, in which the calcification is much more extensive and the joint surfaces are intact.

Infectious Arthritis.—Infectious arthritis attacks any joint at any age. Its forms are extremely varied owing to the different causative agents. Any organism which circulates in the blood stream may

be responsible for it. The most common types are pyogenic, gonorrheal, tuberculous and syphilitic.

Pyogenic arthritis is usually due to staphylococcus, streptococcus or pneumococcus infection. The acute forms attack one or many joints which show soft tissue swelling and effusion in the synovial cavity. The process may then subside with disappearance of these



FIG. 138 --Charent joint.

signs. In the chronic form decalcification of the articular ends of the bones occurs and there is early erosion of cartilage with narrowing of the joint space. In addition to the destruction of cartilage, a characteristic finding is slight irregularity in the outline of the articular surfaces of the adjacent bones, and the presence of multiple small areas of rarefaction close to the joint surface. Later, as repair begins, hypertrophic changes may make their appearance at the

margins of the articular surfaces, or the cartilage may be entirely destroyed and ankylosis result when healing is complete.

Gonorrheal arthritis is usually monarticular but it may be indistinguishable roentgenologically from other infections. There are two findings which are suggestive of Neisserian origin. One is a



FIG. 139.—Infectious arthritis. Note the loss of articular cartilage at points indicated by the arrows and about all of the carpal bones. Characteristic area of erosion at A. General rarefaction of the carpus and articular ends of the long bones.

localized destruction of the cartilage on the under surface of the patella, which sinks in toward the condyles of the femur. Subsequently hypertrophic changes appear on its margins and on the adjacent areas of the femur. The second is the occurrence of small localized areas of rarefaction in the bone at the junction of

articular surfaces and cortex (Fig. 141). Another result of this infection is the development of new bone deposits along tendinous attachments. These spurs may be the result of the activity of other organisms, but the great majority are gonorrheal.

Tuberculosis.—Tuberculosis is more common in children and young adults but may occur in the aged. It is usually monarticular and rarely involves more than two joints. It causes slight enlargement of the soft parts, effusion in the capsule, and general haziness and



FIG. 140.—Gonorrheal arthritis. Lateral view. Areas of erosion indicated by the arrows.

muddiness of the entire joint area. There is extreme decalcification so that the outlines of the bones may be reduced to a thin pencilled white line. Enlargement and squaring of the epiphyses are seen, and later more or less destruction of joint surfaces and interference with the growth of the bone. The limits of the diseased area tend to produce a scalloped pattern, due to the confluence of individual foci of destruction. There is no new bone formation. Occasionally small foci occur in or close to the epiphyses, appearing as localized areas of decreased density, with little or no evidence of joint involvement. A form of tuberculosis, rare in the United States, is that in

which the destructive lesions are associated with a marked periosteal proliferation indistinguishable roentgenologically from that seen in syphilis. The occurrence of periosteal proliferation in the vicinity of these joints is generally the result of secondary infection. During the process of repair there is increase in density, due to deposit of lime salts. A point of difference between tuberculous and pyogenic infections in adults lies in the fact that pyogenic processes attack and destroy articular cartilage very early, and particularly at points of weight-bearing or pressure. In tuberculosis the joint



FIG. 141.—Gonorrheal arthritis, anteroposterior view.

space is preserved until late in the disease, because of the tendency of the infection to spread inward from the margins of the joint and to spare the contacting cartilages (Figs. 31 and 32). Eventually the joint may be entirely destroyed. Bony ankylosis in adults is rare. In old age the disease may be mistaken for septic or hypertrophic arthritis.

Caries sicca is a rare form of the disease seen most commonly in the shoulders, in adults. It causes a ragged erosion of the articular surfaces, no soft tissue swelling, no effusion and no decalcification (Fig. 35).

Syphilis.—Syphilis occurs at any age. It causes increased density in the soft tissues and the occurrence of a slight periostitis at the junction of the periosteum and synovial membrane, occasionally destruction of articular surfaces, particularly those of the small bones such as the carpus and the tarsus, and local lesions in the epiphyses suggesting tuberculous foci. In some cases, as the result

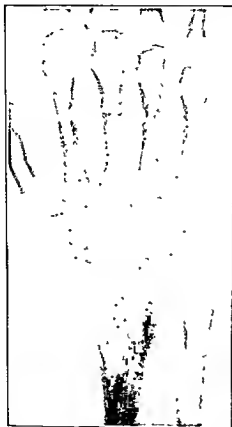


FIG. 142.—Tuberculosis of the wrist in an adult. Marked haziness of the entire carpus. Joint spaces fairly well preserved. No periosteal reaction.

of chronic inflammation in the synovial membrane, low, rounded, hypertrophic ridges will appear at the margins of the articular surfaces.

Still's Disease.—Still's disease is a form of infectious arthritis in children, beginning before the sixth year. There is slowly progressive enlargement of multiple joints, lymph glands and spleen. The affected joints show great enlargement, without evidence of effusion

or suppuration. The bones are extremely rarefied and show finely pencilled outlines.

Villous Arthritis.—Villous arthritis consists of a thickening in the soft parts due to overgrowth of synovial fringes. It may be seen in lateral views of the knee, where the posterior portion of the capsule is occupied by a mass of slightly greater density than normal, with a stringy, fan-shaped shadow radiating anteriorly between the condyles of the femur and the tibia.

Hemophilia.—When the joints are involved in this disease the signs are those of chronic joint irritation suggesting tuberculosis.

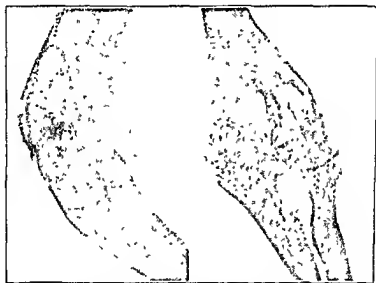


FIG 143.—Hemophilia with organized blood-clot in the capsule of the elbow-joint.

There is rarefaction amounting even to pencilling of the outlines, effusion into the joint, and moderate enlargement and squaring of the epiphyses. At times erosion of the articular ends of the bones may occur, or calcification of the blood-clot within the joint. In late cases the joint is completely disorganized and ankylosed.

Osteochondritis Dissecans.—This condition represents the partial or complete separation of a crescentic area of bone from the articular surface of a joint, usually the knee or hip. The inferior margin of the internal condyle of the femur, adjacent to the spine of the tibia is the common site (Fig. 144). Later on, the fragment may become detached and appear as a loose body in the joint. Loose fragments of semilunar cartilages may behave in the same manner. If they



FIG. 144.—Osteochondritis dissecans



FIG. 145.—Multiple calcified bodies in the knee-joint (osteochondromatosis).

carry a small bit of subarticular bone with them or become calcified, they are clearly visible. As long as they remain purely cartilaginous they cannot be seen. The injection of oxygen gas into the joint followed by the taking of films may clear up the diagnosis.

Osteochondromatosis.—Rarely as a result of a low-grade tumor formation from the synovial membrane, multiple small cartilaginous and bony masses develop within the joint capsule and become free loose bodies, giving a characteristic roentgen picture. (Fig. 145.)

TENDONS AND BURSE.

Effusion or hemorrhage in or about these tissues is shown by an area of slightly increased density with indefinite margins. Synovitis of a tendon sheath may occasionally be suspected from thickening of the shadow and blurring of its ordinarily sharp outlines.

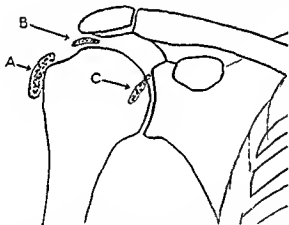


FIG. 140.—Location of the larger bursæ about the shoulder-joint which may be calcified. A, Subdeltoid, B, subacromial, C, coraco-brachial

A particular form of this condition known as de Quervain's disease affects the tendon of the extensor longus pollicis where it lies against the styloid process of the radius. The underlying bone may show a slight periosteal reaction.

Calcification is frequently encountered at tendinous attachments particularly those of the triceps on the olecranon, the quadriceps and patellar tendons on the patella, and the Achilles and plantar tendons on the os calcis.

Areas of increased density seen in the region of the subdeltoid bursa may be true calcifications in the bursa, accumulations of an opaque gelatinous substance in the bursa, or, what is more common,

calcification about the tendon of the supraspinatus muscle beneath it. Calcification may occur in any bursa which has been the seat of trauma or infection causing a mottled, granular, dense shadow which may be distinguished from true bone by the fact that trabecu-



FIG. 147.—Myositis ossificans. Note the dense calcification in the soft tissues about the knee, uniting the femur and tibia.

lation is absent. Large crescentic deposits in the subacromial bursa must be differentiated from the *os acromiale*—a persistence into adult life of the ossification center for the tip of the acromion. Vertical projections of the joint will be helpful in distinguishing between them.

Myositis Ossificans.—A rare disease in which ossification occurs in the soft tissues. There are two forms, one following trauma and the other congenital, of unknown etiology, with a slowly progressive course. In both types there is hemorrhage into the soft parts and a more or less complete ossification instead of the normal absorption. The first form is prone to occur about joints after dislocations, and in muscles subject to trauma such as the quadriceps. The second form practically always has deformities of the fingers and toes associated with it. The terminal phalanges, particularly those of the thumbs and great toes, are short and small, and one or more metacarpals or metatarsals may be greatly reduced in size. The disease is to be differentiated from calcification extending into the soft tissues as a result of periosteal injury and tumors which arise from the bone. In the traumatic form, the calcified mass lies free from the bone and the cortex beneath it is smooth. The sheets of calcification are laid down parallel with the shaft. In the second type the lesions are multiple and extensive due to a progressive ossification of entire muscle groups.

Calcinosis, a deposit of calcium in masses scattered through the subcutaneous tissues, is seen as a rare condition, sometimes associated with scleroderma. One form of the disease occurring in children is known as calcinosis juvenilis.

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CHAPTER VIII.

THE CHEST.

THE shadow of the chest may be divided into: (1) the thoracic wall, (2) the superimposed sternum, heart, great vessels, mediastinum and spine, (3) the diaphragm, and (4) the lung fields.

Pathological processes in the thoracic wall may consist of injuries to the ribs, tumors or infections. A wavy erosion of the intercostal grooves on the ribs occurs in coarctation of the aorta. The ribs may be thickened when they overlie a chronic empyema without a true osteomyelitis being present. There may be an emphysema of the soft tissues, which, as a rule, is associated with fracture of the ribs or surgical interference. In this case, the film is most striking, showing the presence of dark areas representing air scattered through the muscles and subcutaneous tissue.

The central shadow includes: (1) the great vessels, the heart and pericardium, (2) the thymus gland, when present; (3) the thyroid if intrathoracic, and (4) tumors arising from the mediastinum.

The normal thyroid and thymus are not visible in a film of the chest. A substernal thyroid or an enlarged thymus appears as a dilatation of the upper end of the central shadow. An enlarged thymus produces a shadow which is roughly quadrangular. It has rounded lower corners and sharp margins, which extend downward from above the clavicles and overlap the shadow of the heart and great vessels. It is less dense than other tumors. Compression or displacement of the trachea or esophagus may be seen in the anteroposterior or lateral views. Not every shadow in the superior mediastinum of an infant represents an enlarged thymus. One must be particularly careful in making this diagnosis from films taken in expiration, when the diaphragm is high, the heart shadow rather large and the superior vena cava distended. Minor degrees of enlargement of the thymus cannot be demonstrated and they are of no clinical importance.

The thyroid, when intrathoracic, produces a dense, round, sharply defined shadow, which extends downward and overlaps the shadow of the great vessels. It may be differentiated from thymus and other mediastinal tumors by the fact that it moves with deglutition.

Enlargement of the *mediastinal shadow* may be due to enlarged mediastinal glands, tumor, aneurysm, vertebral abscess or dilatation of the esophagus.

Enlargement of the glands is generally due to tuberculosis, Hodgkin's disease, or metastasis from malignant tumors elsewhere in the body. Their outline is sharp and irregular, or lobulated, and the process, as a rule, is bilateral. They do not pulsate, although

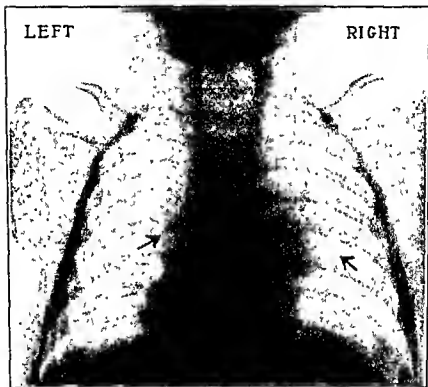


FIG. 148 — Enlarged thymus gland. Note that the shadow is more or less rectangular and overlies that of the upper border of the heart and great vessels.

large masses may transmit the impulse of the heart or aorta. They are to be differentiated from aneurysms and primary tumors of the mediastinum. By means of a careful fluoroscopic examination it is sometimes possible to separate their shadow from that of the aorta, or to demonstrate a normal aorta. The presence or absence of pulsation, as observed in the fluoroscopic examination, is of little diagnostic value, as some aneurysms do not pulsate and mediastinal tumors may appear to do so. Aneurysms are more common in the

ascending aorta to the right of the mid-shadow. They rarely extend upward beneath the clavicle, and are usually single lesions. Masses due to enlarged glands are more likely to appear near the lung roots. As a rule, they are bilateral, and often extend upward beneath the sternum.

The enlarged glands of tuberculous origin generally appear during early childhood. They rarely form large masses during adult life. When the peritracheal glands are involved, the picture may resemble



FIG. 149 — Lymphoma of the hilar glands. An extension from the cervical region.

that of Hodgkin's disease. Tuberculous glands are smaller and more dense and are usually partially calcified except in the early stages of their development.

Benign Tumors.—The most common benign tumor of the superior mediastinum is a substernal extension of an adenoma of the thyroid gland. Unless it is very large it rises to some extent with swallowing. Its position, rounded outline, and the fact that it compresses and displaces the trachea should identify it (Fig. 150).

Other benign tumors are lipomata, teratomata and cysts. They are usually round. They displace rather than invade adjacent organs and they may show a definite capsule. Repeated examinations will demonstrate that they are stationary in size or of very slow growth.

Mention should also be made of neurofibroma, an hour-glass tumor arising in the meninges of the spinal cord, which grows out along the nerve roots, separating the ribs or eroding the surrounding bone, ending in a rounded mass within the chest. On the antero-posterior films these masses may appear to arise from the mediastinum.



FIG. 150.—Substernal thyroid. The outline of the trachea has been dotted in.

Dermoids are usually found anteriorly in the mediastinum, neurofibromata always lie posteriorly.

A dilated esophagus, a large diverticulum or a hiatus hernia of the stomach may overlap the right lung field and be difficult to identify without the barium meal.

Malignant Tumors.—Malignant tumors of the mediastinum produce fusiform or lobular masses, which cause an expansion of the



FIG. 151.—Malignant tumor of the mediastinum, resembling aneurysm.



FIG. 152.—Same case as in Fig. 151, following a series of roentgen-ray treatments. The decrease in the size of the tumor rules out aneurysm.

central shadow and may largely obscure the outlines of the great vessels and the base of the heart. A common tumor is lymphoma, which may be primary in this region or part of a generalized disease. It is more often seen in young adults, but may appear at any age. It is accompanied generally by the enlargement of glands elsewhere in the body. The shadows of the peritracheal glands appear as lobulated masses on both sides of the mid-shadow above the outline of the heart. These shadows extend upward beneath the clavicles. Occasionally there is infiltration of the surrounding lung, which appears on the film or screen as narrow, dense, radiating lines, or there may be a general enlargement of the lymphoid structures throughout the entire chest.

The enlarged glands due to lymphoma disappear rapidly under roentgen radiation, therefore, a favorable therapeutic result may be a guide to correct diagnosis.

Carcinoma is usually a metastatic lesion in the mediastinum. Masses due to it are not as large as those seen in lymphoma. A characteristic feature is their tendency to invade the surrounding structures early in their course. Their margins tend to be hazy and indefinite and if the lung is involved atelectasis may complicate the picture by producing a large area of increased density beyond the actual tumor.

Fibrosarcoma is a rare tumor of slow growth, usually located in the posterior mediastinum. It cannot be differentiated from a benign lesion.

The differentiation of any of these tumors from aneurysms is often extremely difficult. Their position may or may not be that of aneurysm. It is usually impossible to separate their shadow from that of the aorta. The presence or absence of pulsation is of little value as an aid to diagnosis.

THE HEART AND GREAT VESSELS.

In the examination of the heart, the following data should be obtained: (1) the size; (2) the shape; (3) the movements with respiration; (4) the pulsations of the various chambers; and (5) the change of shape which may occur with a change in the position of the patient. The size and shape of the aorta in both its antero-posterior and its lateral diameters should also be noted.

This data may be obtained by means of orthodiagraphy, or by a combination of teleoroentgenography and fluoroscopy.



FIG. 154 — Aortic regurgitation. Note the characteristic enlargement of the left ventricle.



FIG. 155 — Same case as in FIG. 154, taken at 2 instead of 6 feet. Note the distortion of the enlarged left ventricle.

placement of the tube either to the right or to the left of the median line does not appreciably distort the heart shadow, but a slight rotation of the patient does produce a definite distortion.

If the patient is stout, it is better to have the film in contact with the chest wall, and the patient standing erect. If the film is placed at right angles to the central rays, its upper portion may be some distance from the chest wall, and, as absolutely parallel rays are not employed, a slight amount of magnification of the aorta will result. On the other hand, if the patient is allowed to lean forward in order to bring the chest entirely in contact with the film, there will be a certain amount of apparent sagging of the contents of the chest.

The patient should be instructed to remain quiet. It is not necessary for him to hold his breath, nor is it desirable to have him take a deep breath. The amount of movement of the heart shadow during normal respiration is slight, but deep inspiration causes definite changes in both the shape and the size.

The exposure time will vary according to the type of apparatus, but should not be more than one-twentieth of a second. For practical purposes it probably makes little difference what phase of the heart cycle is recorded. For accurate comparison or measurements, films should be obtained in the same cardiac and respiratory cycles.

After the films are developed and dried, the measurements of the heart are taken from them according to the plan adopted by Groedel. This plan includes six points, three points each on the right and left sides of the heart shadow. On the right side, the highest point is at the junction of the heart shadow with that of the great vessels, the second point is at the point of the heart shadow farthest to the right, and the lowest point is at the junction of the heart shadow with that of the diaphragm. On the left side, the highest point is at the junction of the shadow of the left auricle with that of the left ventricle, the second point is at the point of the heart shadow farthest to the left, and the lowest point is at the heart apex. A line is drawn along the center of the spinal column and used as a median line.

The transverse diameter of the supra-cardiac shadow is measured at the widest point above the pulmonary artery.

The greatest distance both to the right and to the left of the median line is obtained. These measurements represent the transverse diameter of the heart shadow. A line drawn from the highest point on the right to the heart apex represents the total length

of the heart, and lines drawn at right angles to it—one from the highest point on the left, the other from the lowest point on the right—represent the diameter of the base.

Measurements of the heart and the internal diameter of the chest combined with the fluoroscopic observations constitute the data from which conclusions are drawn. In order to interpret these

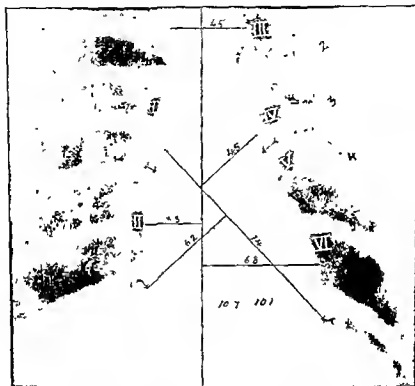


FIG. 156.—Teleroentgenogram of the normal heart and great vessels. On the right, *I* is the ascending aorta, and *II* the right auricle. On the left, *III* is the aortic arch; *IV*, the pulmonary artery, *V*, the left auricle, and *VI*, the left ventricle.

findings correctly, it is essential that the roentgenologist have a thorough knowledge of the anatomy of the heart and great vessels, and of the normal roentgenographic shadow.

Normal Heart.—Normally, the central shadow approximates the outline in Fig. 156. At the top, on the left side, the arch of the aorta appears with the descending aorta extending downward from it. Below the arch is the slight prominence of the pulmonary artery

followed by the left auricle or auricular appendage in the angle between the pulmonary artery and the ventricle. The rounded mass of the left ventricle comprises the largest part of the shadow. The location of the apex is a matter of considerable uncertainty, as it varies with the size, shape and position of the heart, and the position of the diaphragm. It is hidden frequently behind the shadow of the diaphragm. The right border begins at the top with the poorly defined shadow of the superior vena cava above and overlapping the ascending aorta, which is usually well defined as it curves outward and downward to meet the rounded right auricle. The latter joins the right diaphragm at an acute angle, at the apex of which the inferior vena cava is sometimes seen. The right ventricle is not visible in the anteroposterior view, as its shadow is superimposed upon that of the left ventricle and auricles.

The left oblique position is of great value in a study of the arch of the aorta and in estimating the size of the right ventricle. A line is drawn across the base of the heart shadow from the notch between the right ventricles and the aorta to the notch between the left auricle and left ventricle; this is the base line. The point midway between the overlapping portions of the aorta and pulmonary artery is located and a line is drawn from it, perpendicular to the base line, to the lower border of the heart shadow. This line passes along the interventricular septum. Lines perpendicular to it are then drawn to the left and right borders; from these the width of the left and right ventricles is obtained. Since this position gives an unobstructed view of the ascending and transverse portions of the aorta, it is possible to measure with a considerable degree of accuracy the diameters of the aorta at the various levels (Fig. 157).

An ingenious method of obtaining a plastic representation of the heart was suggested by Palmieri, by means of which successive heart profiles obtained during rotation of the patient about a vertical axis could be reproduced on wax models.

The shadow of the heart is subject: (1) to all the laws that govern the size and shape of the shadow of any other object; (2) to the variations due to changes in the position of the heart within the thoracic cavity; and (3) to those conditions which actually change the size and shape of both the normal and the pathological heart. For this reason, a comparison of the measurements of the shadow of any given heart with those made from the organ itself is often misleading and of no value. Comparison should be made only with

the shadows of normal hearts obtained under similar conditions, and the actual size of the heart should not be stated. It should be borne in mind that the measurements obtained do not represent the actual size of the heart—only that of the shadow produced.

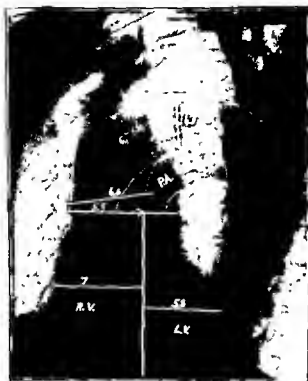


FIG 157.—The second or left oblique view (suggested by Warren) showing the ascending and transverse aorta with the points from which the measurements are taken. The outlines of the aorta and pulmonary artery have been touched.

The following are some of the non-pathological conditions which may change the size or shape of the heart silhouette:

1. The age of the patient is an important factor. In youth the heart tends to hang vertically in the thorax. In old age the long axis moves toward the horizontal. Consequently, in youth the shadow is more nearly round, and in old age it becomes elliptical.

2. When the diaphragm is high the apex is raised, and, to some extent, the entire heart. The shadow is increased principally in its transverse diameter.

3. The height, weight and sex of the patient, and the size and shape of the thorax also influence the size and shape of the heart.

4. Rest in bed for a few weeks may reduce the transverse diameter 5 to 10 mm.

Violent exercise may cause a transient decrease in all the diameters of the heart.

Heart Measurements.—The following table worked out by Claytor and Merrill gives a fairly good guide as to the measurements of the normal heart.

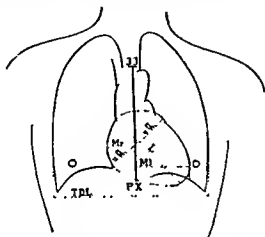


FIG. 138.—Tracing showing the shape of the normal heart and great vessels, and the points from which measurements are obtained (Groedel)

Males (37 cases).

Weight, pounds.	Cases.	Mr.	ML	T. D.	L. D.	
120-129	3	3.0	7.0	10.7	11.8	Minimum
		3.7	7.2	10.9	12.6	Average
		4.3	7.5	11.3	13.5	Maximum
		3.5	7.5	11.0	12.0	Minimum
130-139	5	3.8	8.0	11.8	13.2	Average
		4.2	8.5	12.5	14.0	Maximum
		3.4	7.0	11.0	12.0	Minimum
		4.0	7.7	11.9	13.4	Average
140-149	9	4.6	8.4	13.1	14.5	Maximum
		3.2	7.8	11.5	12.5	Minimum
		3.9	8.4	12.3	13.5	Average
		4.5	9.0	13.0	15.0	Maximum
150-159	8	3.7	8.0	12.0	14.0	Minimum
		4.0	8.2	12.4	14.6	Average
		4.8	9.0	13.8	15.8	Maximum
		3.8	7.0	11.0	14.0	Minimum
160-179	6	4.2	8.7	12.9	14.7	Average
		4.5	9.7	13.4	15.3	Maximum

Females (51 cases).

Weight, pounds.	Cases.	Mr.	ML	T D.	L. D.	
100-109	2	3.2	6.7	9.0	12.0	Minimum
		3.3	6.8	10.2	12.1	Average
		3.5	7.0	10.5	12.3	Maximum
110-119	3	3.0	7.0	10.0	11.5	Minimum
		3.1	7.6	10.7	11.9	Average
		3.2	8.0	11.1	12.4	Maximum
120-129	14	2.3	6.4	10.2	10.5	Minimum
		3.5	7.5	11.0	12.2	Average
		4.2	8.6	12.2	13.8	Maximum
130-139	19	3.0	6.4	9.6	11.2	Minimum
		3.4	7.8	11.2	12.4	Average
		4.0	8.8	12.6	13.3	Maximum
140-149	5	2.6	7.0	10.0	12.2	Minimum
		3.5	7.6	11.1	12.7	Average
		4.1	8.3	11.8	13.2	Maximum
150-159	7	3.1	7.6	10.9	12.3	Minimum
		3.6	8.0	11.6	12.9	Average
		4.8	9.3	12.8	14.2	Maximum
160-175	4	3.5	6.5	10.6	11.8	Minimum
		3.8	7.9	11.7	12.6	Average
		3.8	8.5	12.3	13.0	Mean
		4.1	9.0	12.8	13.2	Maximum

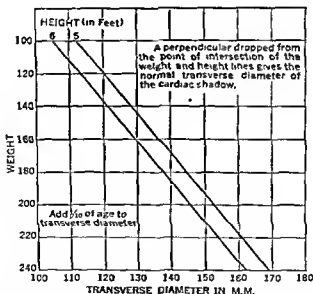


FIG. 159.—A convenient chart for determining heart size based on the Hodges-Eyster formula.

The Appearance of the Heart Shadow in Disease.—It is only occasionally that the roentgen findings are sufficiently characteristic to warrant a definite diagnosis of heart disease without some knowledge

of both the clinical and the physical data. When all of the evidence is correlated the roentgen findings frequently help to either establish or confirm the diagnosis.

There is no other method of examination whereby such accurate data can be obtained regarding the size and shape of the heart and great vessels, and the changes which take place with respiration and change of position. Valuable information may also be obtained regarding the effect of treatment on the size and shape of the heart, and the progress of disease.

Changes in Size.—The size of the heart shadow is increased, as a rule, in luetic, rheumatic and hypertensive heart disease. It is decreased generally in the nervous or irritable heart, in the cachexia of chronic disease, in visceroptosis and in emphysema. In visceroptosis and emphysema the change may be more apparent than real, owing to the low position of the diaphragm. In arteriosclerotic heart disease there may or may not be a true enlargement, although the heart shadow, as a rule, is increased in size. The sagging of the heart which accompanies this condition tends to increase its transverse diameter.

Changes in Position.—As the heart is supported to some extent by the diaphragm, its position changes with change in position of the diaphragm. The heart is high when the diaphragm is high, and low when the diaphragm is low. With extreme elevation of the diaphragm on one side, the heart is displaced to the opposite side. With fluid free in the pleural space, or new growth in the lung, there is a similar displacement unless the heart is fixed by adhesions.

In all conditions causing extensive destruction, and in fibrosis of one lung, partial or complete occlusion of the bronchi, and collapse of one or more lobes, the displacement of the heart is to the affected side.

In the unilateral emphysema caused by foreign bodies and in pneumothorax, the displacement when present is away from the side involved.

The shadow of the heart may appear to be in an abnormal position whenever there is marked deformity of the thoracic wall.

In pneumonia and other forms of consolidation, the position of the heart is generally normal.

Changes in Shape.—The shape of the heart varies with the tone of its musculature. A well rounded apex and an increased curvature on the left border are due to hypertrophy and an increased tone. In myocardial weakness the outline becomes more triangular.

the borders, particularly the left, are straight rather than rounded, and the separate chambers are less distinct.

Enlargement of the heart, whether local or general, is accompanied by changes in shape, some of which are quite characteristic, such as the triangular heart of mitral disease, or the L-shaped heart of aortic regurgitation.

Changes in Outline.—The outline of the normal heart is distinct, and its chambers are sharply defined. In the hypertrophic and vigorous heart, this distinctness is increased. With loss of muscular tone, and in disease of either the pericardium or the mediastinum, its distinctness is diminished.

As the visibility of the heart depends upon its density being greater than that of the air-filled lung surrounding it, any process in the lung which increases its density tends to obscure the outline of the heart.

Pulsation.—The fluoroscopic observation furnishes direct evidence in regard to the character of the heart muscle. Vigorous pulsation usually signifies good muscle tone, while weak, shallow pulsations are seen with loss of tone.

It is possible to distinguish the pulsation of the auricles from that of the ventricles, and to obtain a fair idea of the strength and amplitude of the beat. In slow, strongly pulsating hearts these observations can be made easily. With tachycardia they are difficult. It is possible, generally, to detect an irregularity of the beat, and a comparison of the pulsation of the ventricles with that of the auricles, or with the pulse at the wrist, can be made. In this way heart-block may be diagnosed, and irregularities of the ventricular beat which do not reach the wrist may be discovered.

Following a coronary occlusion, absence of pulsation may be observed over the affected area, if it can be brought into profile.

In auricular fibrillation and extreme dilatation of the auricles, visible pulsation over the auricles is absent. With adhesive pericarditis, or fluid in the pericardium, the beat becomes diffuse, and it is impossible to distinguish that of the auricles from that of the ventricles. When the amount of fluid is large the beat may be absent.

Calcification Within the Heart.—Old infarcts may become calcified, producing a shadow which closely resembles a calcified pericardium. In some cases calcification in the heart valves has been observed fluoroscopically and calcified coronary arteries have been demonstrated on films made at very high speed, using a grid diaphragm.

Differential Diagnosis.—While in the great majority of cases it is not possible to arrive at a differential diagnosis from a study of the roentgen findings alone, some pathological conditions present evidence which is fairly characteristic and which may be of considerable importance in the final summing up of the case.



FIG. 160.—Hypertension. Hypertrophy of the left ventricle shown by the rounded apex. Failing myocardium indicated by the triangular outline and beginning congestion in the lungs.

For this reason it seems advisable to present briefly the roentgen findings in some of the cardiac lesions which are of common occurrence, or in which the roentgen findings may be of the most value.

Congenital Heart Disease.—The roentgen examination may be the only means of establishing a diagnosis in developmental anomalies of the heart. Since these lesions are frequently multiple, an exact anatomic localization of the lesion is not always possible.

With a patent ductus arteriosus the aorta is small, with a marked prominence of the pulmonary artery below it. The heart shadow is enlarged across its base, giving it the so-called "mitral" shape. The curve of the left auricle can be distinguished from that of the pulmonary artery both by its position and by its pulsation time.

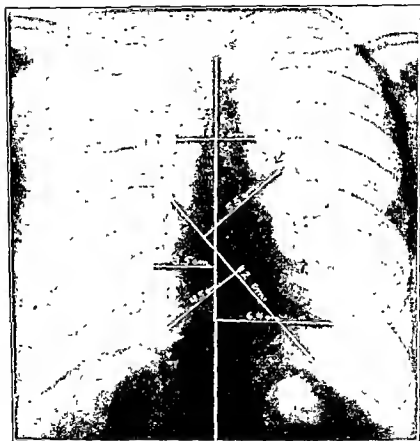


FIG. 161.—Congenital heart disease (patent ductus arteriosus). Note the prominence of the curve of the pulmonary artery as indicated by the arrow.

The shadow of the pulmonary artery may present a somewhat similar appearance in aortic stenosis, but the changes in the heart shadow which accompany this condition are quite different. The enlargement is downward and to the left, giving it the aortic instead of the mitral shape.

Defects of the septum may cause no change in the form of the

heart shadow or an increase in the transverse diameter associated with a general rounding of the outline may be present. With a defect in the auricular septum the aortic shadow is small or absent and the pulmonary conus and arteries are enlarged. Groedel has noted "peculiar ventricular movements" of the right border of the heart when the defect is in the interventricular septum.

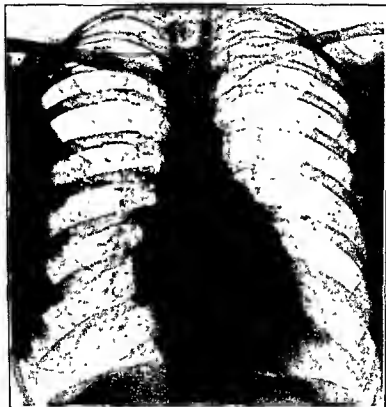


FIG. 162.—Mitral disease. Note the shape of the heart and the small short aortic arch.

Transposition of Heart and Vessels.—In this condition the roentgen appearance depends upon the degree of transposition present. This varies from the shifting of the position of a single vessel to a complete reversal of all the thoracic organs. Complete *situs inversus* is easily overlooked on routine films unless careful attention is paid to identifying marks. On the fluoroscopic screen the condition is obvious. When the transposition is limited to the aorta the roent-

gen examination may be of considerable importance as these patients often complain of difficulty in swallowing and a lesion in the esophagus may have been suspected. The usual aortic knob is absent but may be seen on the right side. The usual bulge of the ascending aorta is also absent and when a swallow of barium is given it will be seen to pass to the left instead of to the right of the aorta.

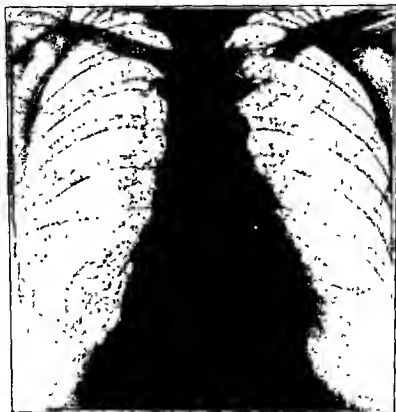


FIG. 163.—Myocardial failure. Note the triangular shape of the heart and the congestion in the lungs

Rheumatic Heart Disease and Lesions of Infectious Origin.—If the disease is at all advanced the shadow of the heart will be increased in some of its diameters, and its shape will vary from that of the normal. As this condition generally involves one or more of the heart valves, most often the mitral, the characteristic findings are a general enlargement of the heart shadow with marked prominence of the chamber corresponding to the diseased valve.

When the lesion is confined to the mitral valve, and both stenosis and regurgitation are present, the findings are: (1) the shadows of the auricles are prominent; (2) the measurement is increased to the right and upward; and (3) the shape of the heart shadow is more nearly round. If stenosis predominates, there is a marked prominence of the shadow in the region of the left auricle and pulmonary



FIG. 164 —Diseased aortic valve. Hypertrophy of the left ventricle, arteriosclerosis

artery, with only a slight increase in the size of the other chambers, and the shape is more triangular. If regurgitation is the predominating symptom, the enlargement to the right is more marked. In either case the shadow of the aorta becomes relatively unimportant and in marked cases almost disappears. The right oblique view is especially valuable in demonstrating the left auricle.

With involvement of the aortic valve, the picture may resemble

very closely that of syphilitic heart disease. However, the absence of changes in the shadow of the aorta is a valuable diagnostic point in favor of a non-syphilitic origin.

In advanced cases with broken compensation, the shadow of the heart is enlarged to a marked degree in all diameters, but the shadow of the auricles still predominates and there is mottled density extending outward from the lung roots due to congestion. A characteristic fibrosis may develop about the lung roots following long-continued passive congestion.

Syphilitic Heart Disease.—When syphilis attacks the heart, the lesion is usually found near the aortic valve. It may affect the root of the aorta, the mouths of the coronary arteries and the aortic cusps, and sometimes all three are involved. The findings vary somewhat according to the area involved and the extent of the lesion.

Prominence of the aortic shadow to the right, with actual increase in its diameter at the root is a most constant finding. With involvement of the coronaries, there is a slight increase in the size of the heart. The outline of the chambers become less distinct, and visible pulsation is diminished. When the aortic valves become incompetent as a result of the disease, there is an increase in the size of the shadow of the left ventricle. The outline of the left border becomes more convex, and the apex appears blunted.

In typical cases the supracardiac dulness is increased, the increase being most marked to the right. The heart lies more horizontal in the chest, and its shadow is increased to the left, giving it the so-called "sabot" shape. As the disease progresses and the chambers become dilated, the findings are not so characteristic.

The roentgen evidence of syphilitic heart disease differs from both that of arteriosclerotic heart disease and that of hypertensive heart disease largely in the appearance of the aorta and the position of the heart.

Arteriosclerotic Heart Disease.—In arteriosclerotic heart disease, the heart shadow may show no variation from the normal either in size or in shape. There is usually an increase to the left, and a prominence of the curve of the left ventricle.

When the coronary arteries are involved the outline of the various chambers may be indistinct, and the beat flabby or irregular.

Calcification in the coronary arteries has been demonstrated by extremely fast exposures, using a Lasholm grid. Their shadows must be differentiated from calcification in the heart valves, costal cartilages or hilar glands.

The most constant finding is elongation of the aorta. Its shadow is increased to the left in the region of the arch. The knob becomes extremely prominent. There is also some increase to the right, although the actual diameter is not increased. Occasionally, dense, calcified plaques can be made out. When these cases are complicated by high blood-pressure, or broken compensation, the findings are most difficult to interpret.

Cardiac Aneurysm.—Most of the aneurysms of the left ventricle occur above the apex or on the posterior wall. Unless they are seen exactly in profile they may not be recognized. When very large they usually extend beyond the right border of the heart in the anteroposterior view. Aneurysms of the left auricle almost always project beyond the right border of the heart. Old infarcts in the heart muscle, if they become calcified, may be mistaken for calcification in the pericardium.

Hypertensive Heart Disease.—The enlargement of the heart shadow is almost wholly in the region of the left ventricle. The increase is downward and to the left, as in aortic regurgitation, but the downward increase is more marked and the apex is not so blunt. The pulse-beat becomes prominent, and there is generally a diffuse enlargement of the shadow of the great vessels.

Auricular Fibrillation.—In auricular fibrillation, there is an extreme enlargement of the shadow of the auricles with absence of visible pulsation in them. In certain cases the heart shadow appears to rock.

Heart-block.—In this condition, if the pulsation is not too rapid, it is possible to compare the auricular and ventricular beats, and to determine their respective rates.

Myxedema Heart.—In myxedema the heart is enlarged in all diameters, and roughly triangular in outline. After appropriate treatment with thyroid substance the outline is reduced in size.

Ayerza's Disease.—Ayerza's disease is a condition in which a gradually increasing cyanosis develops as a result of changes in the pulmonary vessels. Films show a prominence of the pulmonary artery and masses of dilated bloodvessels about both lung roots which may show active pulsation. The right heart is enlarged and the transverse diameter is increased.

Pericardial Effusion.—With fluid in the pericardium, the heart shadow tends to become triangular in shape, the apex of the triangle being in the region of the great vessels.

When the patient is in the prone position there is an increase in

the width of the triangle at the apex. With the patient in the upright position there is an increase at the base, and the shadow often assumes a water-bottle shape.

The cardio-hepatic angle rarely is obliterated, although it may seem to be so upon percussion. The left border of the heart shadow loses its normal curve, appearing as a straight line, and the point of contact of the auricle and ventricle cannot be made out.



FIG. 165 — Pericardial effusion (patient in the upright position). Note the "water-bottle" shape of the heart shadow.

Pulsation is either considerably diminished or entirely absent. The character of the pulsation also is changed. The beat of the ventricles is indistinguishable from that of the auricles, the impulse being more or less general over the entire left border.

In obtaining the outline of the heart in different positions for comparison, it is not wise to depend wholly upon screen observations. A careful tracing of the heart under the fluoroscope should

be made, and films should be obtained in both the prone and the upright positions at a distance of 6 feet. The outlines thus obtained should be superimposed.

An amount of fluid up to 500 cc. may be present in the pericardium without showing any roentgenological evidence of its presence.

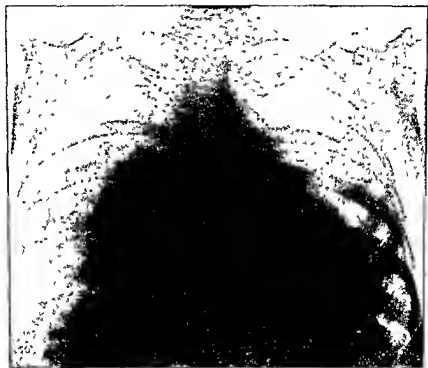


FIG. 166.—The same case as Fig. 165, but taken with the patient prone. Note the change in the shape of the heart shadow, due to the shifting of the fluid within the pericardium.

The differential diagnosis is usually between fluid in the pericardium and a dilated heart, and it is based largely upon the presence or absence of change in the shape of the heart shadow with change in position of the patient. Encapsulated fluid may be mistaken for an enlargement of one of the heart chambers.

Adhesive Pericarditis.—It is not possible to differentiate the shadow of the heart from that of the pericardium, except in those rare cases in which the pericardium contains air as well as fluid. There is

likely to be some haziness in outline of the heart shadow, and an apparent obliteration of the angles between it and the diaphragm. The shadow of the auricles cannot be distinguished from that of the ventricles, and the movement of the heart with respiration and change of position is limited. There is usually a general increase in size, and pulsation may be diminished or irregular.

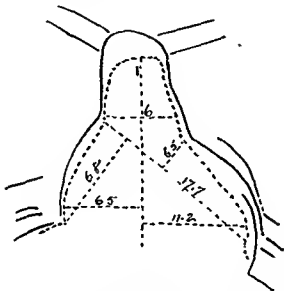


FIG. 167.—Tracing showing the limited respiratory movements of the heart in adhesive pericarditis.

A calcified pericardium is seen occasionally. It occurs in the form of a shell of calcium density about the apex or surrounding a considerable portion of the heart. Pulsation is absent. The differentiation between a calcified pericardium and a similar process within the heart muscle may be extremely difficult. The process in the pericardium is the residue of an old infection, commonly tuberculosis, and is usually accompanied by other evidence of an old mediastinitis.

The Aorta.—Anatomical variations of the thoracic aorta are rarely diagnosed during life. There are two conditions, however, which present a fairly characteristic roentgen appearance as well as being of considerable clinical importance. The first, coarctation of the aorta, is a well-known postmortem finding and consists of marked narrowing or obliteration of the lumen of the aorta opposite, or a

little below the insertion of the *ligamentum arteriosum*. The collateral circulation is set up by the costocervicals, internal mammaries, and the descending branches of the transverse cervical above the stenosis, and below it by the intercostals, the pericardiophrenics, and the superior and inferior epigastrics, with enlargement of all these vessels. On examination with the roentgen-ray in the antero-posterior view the aortic knob is usually absent, the ascending



FIG. 165.—Aneurysm of the aortic arch.

aorta is prominent, and the heart is usually enlarged. In a film taken in this position erosion of the ribs due to the enlarged intercostal arteries is often seen; in the second oblique position it is sometimes possible to demonstrate a stricture, or the absence of the usual shadow cast by the descending thoracic aorta. The second anatomical variation is malposition of the arch and descending aorta. The aorta passes to the right instead of the left,

and may extend downward on the right side of the spine, or it may cross the spine to the left side behind the heart. The roentgen findings in this condition also show an absence of the aortic knob in the anteroposterior view, and by rotating the patient into an oblique position it is usually possible to demonstrate the abnormal position of the aorta; the heart may or may not be enlarged; the trachea and esophagus are displaced forward and lie anterior to the aorta. The clinical importance of this condition is due to the fact that additional anatomical variations of the vessels of the neck may occur—the subclavian artery extending into the neck in such a manner that it is mistaken for the inferior thyroid artery.

Increase in the supracardiac shadow, as seen roentgenologically, occurs most frequently as the result of lues, arteriosclerosis or high blood-pressure.

In very large hearts there seems to be a relative enlargement of the aortic shadow. The aortic shadow is also slightly wider in cases with a high diaphragm than in cases where the diaphragm is low. Probably some of these variations are due to the difference in the shape of the aortic arch. If the arch is wide, there is less overlapping of the ascending and descending aorta, and consequently, the diameter of the shadow is increased.

Luetic aortitis commonly appears first just above the aortic valves, and as the wall of the aorta becomes weakened there is a bulging of this area, which appears as a variable prominence of the right border above the shadow of the auricle. By rotating the patient before the fluoroscopic screen, an actual increase in the diameter of the base of the aorta can be demonstrated. The shadow may have the appearance of a cone with its base upon the heart shadow. In advanced and atypical cases the dilatation of the aorta may be general. There is usually an increase in pulsation, and the shadow of the heart may have either an enlargement to the left or an appearance of flabbiness.

In arteriosclerosis the calcified plaques in the aorta are not visible unless quite extensive. The tortuous aorta, however, does present a definite, characteristic change in the appearance of the aortic shadow. There is a distinct, sharp increase in the upper part of the shadow to the left, and often the appearance of a knob at the junction of the transverse and descending portions. When viewed obliquely the aorta will be seen to be of normal, or nearly normal, size.

In many cases of long-continued high blood-pressure, there is

a diffuse dilatation of the aorta which cannot be differentiated from that of the diffuse luetic type by roentgen evidence alone; or there may be a combination of diseases present, making the diagnosis most difficult, and, at times, impossible. A careful fluoroscopic study should be made of these cases, comparing the oblique shadow with that obtained in the anteroposterior view, and noting the amount of expansion with each pulsation.

Pulsation is diminished in arteriosclerosis; it is increased in aortic regurgitation and high blood-pressure.

Aneurysm.—The size, position and location of aneurysms of the aorta are seen both on the film and on the fluoroscopic screen in sharp contrast to the surrounding lung structure. If the lesion occurs in the subclavian artery, or in the vessels of the neck which are not in contact with the lung structure, the aneurysm is invisible.

Aneurysms of the ascending aorta are seen to the right, whereas aneurysms of the arch usually appear high up to the left of the spine. Aneurysms of the descending aorta appear in the lower portion of the aortic shadow to the left, and may be partially hidden by the shadow of the heart. Large, diffuse aneurysms may appear as a general increase in the shadow of the great vessels.

Dissecting aneurysms are difficult to recognize. Ordinarily they cause a diffuse enlargement of the central shadow. At times a dilatation of the descending portion may be evident, but this is usually obscured by fluid in the left pleural space.

The pulsations of aneurysms are not always seen on the fluoroscopic screen. It is extremely difficult to differentiate between expansile and transmitted pulsations; therefore, the presence or absence of pulsation, as observed fluoroscopically, is not of conclusive value in the diagnosis. The position of the sac is of more importance. Its outline should be sharply defined, and the shadow of the aorta should be obscured by it.

Mediastinal tumors, other than aneurysms, are not as sharply defined. Their position may be nearer to either the front or the back of the chest than that of the great vessels, or they may occupy a position either higher or lower than that usually occupied by aneurysms. Occasionally, the shadow of a normal aorta may be seen through that of a mediastinal tumor. They displace the heart and aorta more frequently than aneurysms, but do not cause enlargement of the heart, which so frequently accompanies aneurysms.

Mediastinitis, with or without abscess formation, may cause both an increase in size and a change in shape of the mid-shadow. Tuberculosis and lues are, perhaps, the most common causes. The mediastinum rarely becomes infected with one of the pyogenic organisms; if it does, the point of invasion is often by way of the interlobar septum.



FIG 109 —Mediastinal effusion. Note the marked increase of the mid-shadow, through which the shadow of the heart is visible. Arrows indicate the borders of heart.

The roentgen findings are fairly characteristic. The mid-shadow is enlarged, and roughly triangular in shape, with its base upon the diaphragm. Its outline is irregular and indistinct, and the outline of the cardiac shadow can be seen through it. There

is no visible pulsation, and the shape of the shadow does not change with a change in position of the patient. The respiratory movements of the heart and diaphragm are limited, and in some cases paradoxical. This sign when present is almost pathognomonic. It is best observed with the patient in the upright position, and the tube in the direct lateral position. Upon deep inspiration, the shadow of the heart will be seen to follow that of the sternum instead of moving downward with the diaphragm. In this view, the bright spaces generally seen in front of and behind the mid-shadow are either obscured or obliterated.

In atypical cases the enlargement may be to one side only, and, should fluid be present, the shadow becomes denser and more sharply defined. In some cases, where the fluid is encapsulated, the appearance closely resembles that of mediastinal tumor.

The shadow produced by mediastinitis is not in itself sufficiently characteristic to permit of a diagnosis as to its etiology, except in cases where other organs are involved. Tuberculous mediastinitis is accompanied invariably by a tuberculous process in the lungs. In luetic mediastinitis, the changes in the heart and great vessels characteristic of this disease are frequently seen. The pyogenic forms may show thickening along an interlobar septum.

The conditions most likely to be confused with mediastinitis are pericarditis, with or without effusion, and mediastinal tumor. In the differential diagnosis, the finding of greatest value is the paradoxical movement of the heart with forced respiration. This does not occur in the absence of mediastinitis. The next most important sign is the clear outline of the heart showing through the enlarged mid-shadow, which rules out pericarditis with effusion. The other findings, such as absence of pulsation and irregularity of outline, may be present in either disease.

The shadow of fluid in the mediastinum, whether encapsulated or not, generally appears lower in the chest than the shadows produced by enlargement of the glandular structures, or by primary tumor. It is not uncommon for the shadow of mediastinal abscess to extend to the diaphragm, whereas the shadows of enlarged glands, or of tumor, rarely appear below the hilus region.

Perivertebral abscess generally produces a more or less fusiform shadow which appears on both sides of the central shadow. It may be confused with the shadow of the aorta. As this condition frequently results from a lesion in the spine, the recognition of a destructive process in the vertebræ is of considerable importance

in the diagnosis. Films obtained in the lateral view are of great value, as they show the bodies of the vertebrae much better than those obtained in the anteroposterior view. They also show the location of the mass in or behind the posterior mediastinum.

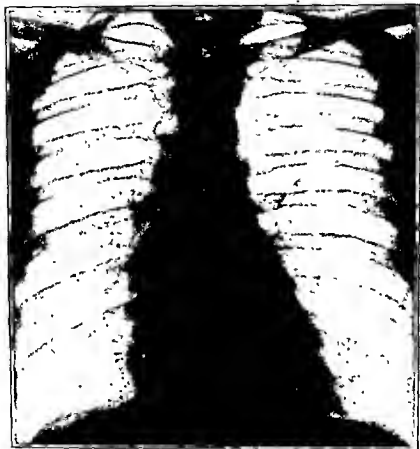


FIG 170—Dilated esophagus due to cardiospasm overlying right border of heart and mediastinum. Compare with Fig 169.

Occasionally in cardiospasm, the esophagus may be dilated to such an extent that it appears as a long, smooth shadow curving outward into the right lung field. It may be more easily recognized when it continues upward above the clavicles. The administration of a barium meal will also confirm its identity. A diverticulum of the esophagus may simulate the appearance of mediastinal tumor, encapsulated empyema or aneurysm.

The Diaphragm.—The normal diaphragm curves smoothly downward from the pericardium and forms a sharp angle with the pleura. The right side is higher than the left (1 cm. or more), and in some cases there are several small curves near the dome, which are due to minor irregularities in the upper surface of the liver and have no pathological significance. Fluoroscopically, the diaphragm should be seen to move freely and equally on both sides during both quiet and deep respiration.

Changes in Outline.—The conditions which may cause changes in the outline of the diaphragm are: (1) irregularities upon the surface of the liver; (2) masses directly below the diaphragm, which tend to transmit their shape to the shadow of the diaphragm during forced inspiration; and (3) bands of adhesions to the pleura, or the chest wall, which elevate small, stringy or triangular areas, and thus change the outline of the diaphragm.

The outline of the diaphragm becomes obscure whenever there is a process in the adjoining lungs which prevents their proper aëration, and when there is an accumulation of fluid in the pleural space. In the presence of any considerable amount of fluid, the outline of the diaphragm is entirely obliterated. When these conditions are present, the position of the diaphragm on the left side may be obtained by placing the patient in the upright position and having him swallow a few times. This procedure increases the size of the gas bubble in the fundus of the stomach, thereby bringing it in contact with the under surface of the diaphragm.

Changes in Motility.—A slight limitation of motion may be observed when the patient is breathing quietly, which disappears completely upon deep respiration.

Bilateral limitation of motion may be caused by emphysema, ptosis, ascites, peritonitis, pleuritis at the base of both lungs, or extensive fibrosis from any cause. Unilateral limitation may be due to inflammatory conditions above or below the diaphragm, such as pleuritis, a diseased appendix or gall-bladder, subdiaphragmatic abscess and perinephritic abscess.

When the inflammatory process is in direct contact with the diaphragm, either above or below it, there is, as a rule, a complete loss of respiratory movement. Any condition which interferes with inflation or deflation of the lung will also cause a decrease in the respiratory movements of the diaphragm on the affected side, examples of which are foreign bodies or new growth in the bronchi, and extensive destructive processes in the lung substance.

Paradoxical excursion of the diaphragm is seen in paralysis of

the phrenic nerve, and diaphragmatic hernia. The side affected rises during inspiration, and falls during expiration.

Changes in Position.—The diaphragm is low in ptosis and emphysema. It is high in obesity, ascites and subdiaphragmatic abscess.

In eventration and hernia of the diaphragm, the elevation is generally confined to the left side. In eventration, the diaphragm is considerably elevated, but its movements are normal, although somewhat limited. In hernia, its outline is obscured and its movements paradoxical. In either case, the administration of a barium meal will demonstrate the position of the abdominal viscera. In emphysema, both the inspiratory and the expiratory movements are limited in all positions of the patient. With visceroptosis, the expiratory movements are not limited, and the inspiratory movements are limited only when the observation is made in the upright position.

Subdiaphragmatic Abscess.—Subdiaphragmatic abscess may cause marked upward displacement of the shadow of the diaphragm. If the collection of pus is in contact with the diaphragm, excursion is absent. When the infection has extended into the chest and involved the pleura, the outline of the diaphragm becomes obscure, and it is not possible to determine from the roentgenogram whether or not there is disease below it. Occasionally, a subdiaphragmatic abscess contains a gas bubble, below which there is a fluid level which changes with change of position of the patient. For this reason these cases should be examined in the upright position when possible.

Encapsulated fluid above the diaphragm may closely resemble subdiaphragmatic abscess if the collection of fluid is between the lung and diaphragm.

LUNG FIELDS.

An examination of the lungs should include both fluoroscopy and films, preferably with the patient in the erect position. In certain conditions, examination in the prone, oblique and lateral positions should be made.

The number and position of the films desired should be determined at the time of the fluoroscopic examination. It is not necessary to take stereoscopic films as a routine procedure, but in selected cases they may be of considerable additional value.

Normal Lung.—In the antero-posterior view the normal lung markings represent the bronchi, bloodvessels and lymphatics, of which the bloodvessels are the most important part. Any condi-

tion which produces an enlargement of the bloodvessels causes a definite increase in the size and density of the lung markings. The normal shadows spread outward from the hilar regions through the lung fields for a considerable distance, but rarely reach the pleura. The shadows in the region of the descending bronchi on both sides are generally more dense than those in the upper portions of the lung.

The hilar shadows vary in size and a considerable experience is necessary before one is qualified to distinguish between their normal and pathological appearances. The roentgenologist must have a fairly accurate idea of the course and distribution of the main bronchi within the various lobes. Careful study of stereoscopic films and of lipiodol injections is extremely valuable in this connection.

In the lateral view, the hilar shadows are obscured by the heart and only the coarser lung markings are well shown. This is the best position to demonstrate the interlobar septa and the retrocardiac space.

The size and density of the lung markings depend upon the quality of the film. It is important that the exposure time should be sufficiently short to arrest heart motion. Overexposure obscures the markings. Motion increases their size and blurs their outlines. Films obtained during expiration, or when the lungs are incompletely expanded, show an accentuation of the shadows in the lower lobes due to a decrease in air content and an increase in the size of the bloodvessels. The most distinct films are obtained by an exposure made at a relatively long, target-film distance, while the lungs are well expanded and the patient is absolutely quiet. The markings are more prominent in the old than in the young, and in all patients who have been exposed to a dusty or smoky atmosphere.

Repeated infection of the respiratory tract generally produces permanent enlargement of the lymphoid structures of the lungs, which shows on the film as an increase in size and density of the lung markings.

The lung fields are of equal density on both sides. They are slightly obscured by the pectoral muscles and the breasts in the postero-anterior view, and, as a rule, there is slight haziness at the left base in the region of the apex of the heart.

Accessory lobes may be recognized if they are surrounded by somewhat thickened pleura. The most common example is the azygos lobe, which occurs at the right apex. Its outer margin is defined by a pleural band which usually carries several small vessels within it, and which has the shape of an inverted comma. Other accessory lower lobes have been observed. Slight tenting of the

right diaphragm close to the heart, representing the pleural attachments along the lateral borders of a small accessory lobe in this region is sometimes seen. Any of these lobes may be atelectatic or cystic.



FIG. 171.—Normal chest. Exposure made at the end of inspiration, with lungs completely inflated.

Pathological Changes.—Diffuse increase in density in one or both sides is found in extensive pleuritis—with or without fluid—massive pneumonia, and occlusion of a main bronchus. A general increase in radiability is due usually to emphysema. Localized areas of diminished density may be due to pneumothorax or cavity formation. Annular shadows usually mean cavities, but emphysematous

blebs and congenital cysts will give a similar appearance. Localized areas of increased density are due to consolidation, fibrosis, new growth, abscess, infarct, and to any other process which excludes the air from an area of lung tissue.

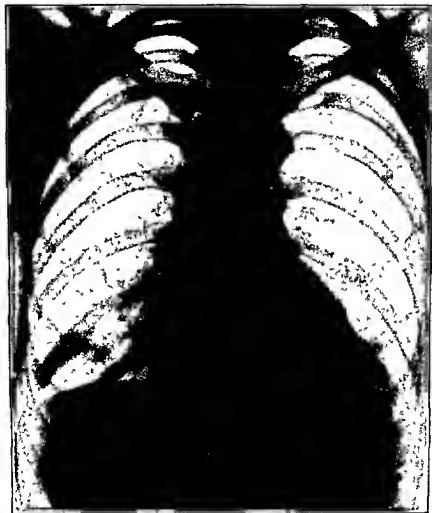


FIG. 172.—Same case as in Fig 171; exposure made at the end of expiration, with lungs deflated.

The root shadows are enlarged in malignant disease involving glands in this region, in infections, long-standing passive congestion of the lungs and silicosis.

The lung markings are increased in size and density in most

infectious diseases of the lungs, and in all systemic diseases which cause a general glandular enlargement, such as lues and Hodgkin's disease. Malignant disease, either primary or metastatic, may spread along the lymph channels producing an increase in their shadows.

Fine mottling or beading along the bronchi is an early manifestation of tuberculosis, but may be due also to other causes. Fine mottling in the lung tissue generally indicates tuberculosis, malignant disease or fibrosis. A diffuse mottling of considerable density may be present for months or years following the injection of lipiodol into the bronchi.

Displacement of the mediastinum occurs in conditions where the balance of pressure on the two sides is disturbed, if no adhesions are present. The displacement is away from the affected side in large effusions, pneumothorax or extensive tumor formation. The shift is toward the affected side in any condition which prevents expansion of the lung or causes extensive destruction of lung substance.

Emphysema results from a variety of causes. It produces a lung which is abnormally bright when seen fluoroscopically and a diaphragm which is low with very little movement on respiration. Radiographically, the lungs are dark, with well defined bronchial patterns. In occasional long-standing cases, large blebs resembling local collections of air in the pleura, several inches in diameter, may be seen. Stereoscopic and lateral films, in addition to the clinical evidence, will establish the diagnosis.

Tuberculosis.—The primary focus in tuberculosis is probably in the periphery of the lung, but it is not always evident. However, an increase in the root shadows is often seen as a result of glandular involvement, which, in children, is generally pronounced. In the acute stage, their outlines are blurred and indistinct. If healing occurs, the shadows gradually diminish in size, increase in density and sharpness of outline, and subsequently show areas of calcification. If the infection progresses, there is a general thickening of the bronchial markings along the track of the disease, usually more pronounced toward one or both apices. When this has occurred, the clinical examination may reveal dullness at the affected area. When the extension of the disease is downward, it is difficult to recognize in the early stage, owing to the normal thickening toward both bases. However, extension in this direction is unusual.

The films of most adult lungs show a certain amount of thickening of the bronchial markings as a result of previous infections, which have no pathological significance. The demarcation between

the normal and pathological lung is not sharp, and it requires considerable experience in the observation of films, combined with complete clinical data, to avoid errors in interpretation.

If the process continues, small, bead-like masses appear along the course of the thickened bronchial shadows, and triangular areas of *filmy density* may be seen with their bases on the pleura and their apices extending inward toward the thickened markings. These triangular areas are probably the earliest evidence of a definite involvement of the parenchyma of the lung but unfortunately they are not easily seen and may occur in other infections.



FIG. 17J.—Tuberculosis at both apices

In the next stage of the disease, finely stippled, grayish spots appear throughout the involved area, apparently independent of the bronchial markings which now extend to the periphery of the lung. These spots denote definite involvement of lung tissue. Clinical examination at this time, may show the presence of rales. This characteristic fine mottling is the only safe basis for a roentgen diagnosis of tuberculosis, and it is present in its most typical

form in miliary tuberculosis. With further progress of the disease there is an enlargement and fusion of these spots, resulting in a coarse mottling, and finally the appearance will be that of consolidation, fibrosis or cavity formation.

Areas of healing may occur at any time, or progress and healing may occur simultaneously, so that it may be impossible to decide from roentgen evidence alone whether or not a case is active or quiescent. In general, active lesions are dim, gray and blurred; healed lesions are more dense and sharply outlined.



FIG. 174.—Peribronchial tuberculosis. Advanced tuberculosis two years later.

Consolidation.—The consolidation of tuberculosis does not differ to any great extent in its roentgenological appearance from that produced by other causes. The correct interpretation of these shadows, therefore, depends to a considerable extent upon additional data, the most important of which is the history of the case. There are, however, certain observations that the roentgenologist should make which may be of considerable diagnostic value.

Tuberculosis commonly begins in the upper posterior portion of the upper lobes. In a few cases, particularly in young persons, the disease may first appear in the lower lobes. It tends to become

bilateral, and is accompanied frequently by disease of the pleura. In portions of the lung, other than those in which the major process occurs, the characteristic fine mottling of tubercle formation may be observed. The demonstration of a round, bright area in which there is absence of lung markings is indicative of cavity formation. The demonstration of cavities is of great value in both diagnosis and prognosis.

The shadow of consolidation from any cause is quite dense, but as a rule the ribs can be seen through it. In tuberculosis, the shadow is likely to be more mottled than in other lesions, and somewhat less dense. It is also less likely to be confined to the region of a single lobe, and its borders are not so well defined.

Fibrosis.—Fibrosis appears on the film or screen as an increase in the lung markings which are dense and sharply outlined. This process often results in the displacement of adjacent organs toward the affected area.

Cavity.—The cavity of tuberculous origin appears as an area of diminished density in which there is an absence of lung markings. These cavities generally appear at the apex of a lobe or in the upper part of the lung field. They vary greatly in size, are frequently multiple and their outlines are irregular. There are three types depending upon the stage of the process and the patient's resistance. The first shows an irregular mottling in an infiltrated area, representing a fairly acute process; second, are the round cavities with a thin wall—the thinner and more dense the wall the better the prognosis; third, the fibrotic cavities with a heavy wall—evidence of chronicity of the process and resistance of the patient. In older individuals this type of cavity is often a source of contagion. Tuberculous cavities are less apt to show fluid levels than pyogenic lesions. However, small fluid levels are seen and occasionally films made after a fit of coughing may demonstrate that an area of apparent consolidation was a cavity filled with secretion. Serial films made on the same individual will show considerable variation in the size of cavities and in the extent of the infiltration about them.

Miliary Tuberculosis.—Miliary tuberculosis presents a characteristic fine, hazy mottling scattered throughout the lung fields. This mottling, as a rule, is more marked in the upper parts of the chest, but it may be quite evenly distributed throughout the entire lung fields. The shadows are not dense, and may be easily overlooked if the film is blurred by motion or overexposed. They are rarely observed on the fluoroscopic screen, and unless there is further

evidence of tuberculosis in the chest, such as calcified masses at the lung roots or fibrosis at the apex, the lesion is generally overlooked in the fluoroscopic examination. One occasionally sees a lung field dotted with small calcified spots, representing miliary lesions which have healed. Many of these are undoubtedly due to tuberculosis.



FIG. 175 —Miliary tuberculosis of the lungs. The changes are most marked in the upper lobes.

Miliary tuberculosis must be differentiated from several other processes. Pneumoconiosis and metastatic malignant disease are the most common causes of confusion.

In rare instances metastatic malignant disease appears as definite, small, discrete areas of increased density scattered throughout both lungs; but the spots, although approximating those of miliary tuberculosis in size, are more dense and more sharply defined.

Miliary tuberculosis may be differentiated from pneumoconiosis by the fact that it is a more diffuse process involving all portions of the lung uniformly, whereas pneumoconiosis typically involves symmetrical areas and spares the apices and bases. The mottling of pneumoconiosis is also more dense, and the spots are more irregular in shape and larger than those observed in tuberculosis.

Boeck's Sarcoid.—The etiology of this disease is not known. The common manifestations are seen in the skin, but it can probably involve any organ of the body. When it manifests itself in the chest it is characterized by symmetrical enlargement of the hilar glands. In a considerable percentage of the cases there is also fine mottling along the course of the larger bronchi; rarely this mottled appearance extends to the periphery. The apices and bases are usually spared. The process is a chronic one, and is usually accompanied by slight irregular elevation of temperature. The appearance on the roentgen film may be confused with tuberculosis or Hodgkin's disease. It may be differentiated from tuberculosis by its distribution, and the fact that calcification or cavity formation does not take place; and from Hodgkin's disease by the absence of involvement of the peritracheal glands, and the symmetry of the lesion.

Lobar Pneumonia.—Lobar pneumonia is characterized by sharply defined areas of increased, uniform density, which, when fully developed, generally occupy the position of one or more lobes.

In the early stages the shadow, although uniform, is less dense, and may be triangular in shape, with the base on the pleura and the apex toward the hilum. The lung markings in this area are thickened and the hilum glands are enlarged. It has been observed in children that dulness and changed breath and voice sounds are not ordinarily perceptible until the shadow reaches the hilum. The shadow changes with the progress of the disease, and, as resolution appears, becomes distinctly mottled. After the shadow itself has disappeared, thickened, bronchial markings or large glands may persist for a considerable time.

The differentiation between lobar pneumonia and pleural effusion may present considerable difficulty at times, particularly when the fluid is localized in pockets between the lobes or overlying them. Lateral films are essential for a proper interpretation. Fluid shadows seldom correspond exactly to lobar outlines.

Bronchopneumonia.—Bronchopneumonia occurs more frequently than is generally recognized. Owing to the absence of physical signs, the diagnosis may depend largely upon the roentgen examina-



FIG. 176.—Lobar pneumonia. Note that the shadow is of uniform density, and corresponds roughly with the region of the lobe



FIG 177.—Bronchopneumonia, following operation upon the nose (postmortem)

tion and the history. The appearance is that of single or multiple areas of increased density generally located near the course of the larger bronchi. These areas are of varying size, and their outlines are hazy. The lesion is usually multiple. There is frequently a considerable variation in the density of different parts of the same area, as well as between the different areas. The central portion may become quite bright, but the lung markings are never completely absent, as in cavity formation. These processes rarely reach the pleura, and there is generally absence of interference with respiratory excursion.

The differentiation of bronchopneumonia from abscess, bronchiectasis and malignant disease depends largely upon the course and clinical history.

The roentgenological observations which are of importance in the differential diagnosis are the presence or absence of atelectasis, cavity formation and the number and size of the lesions.

Abscesses are generally single lesions, and, except in the early stages, contain a definite cavity. Shadows due to bronchiectasis change with the amount of secretions in the bronchi and there is more definite enlargement of the bronchi. In malignant disease the areas are generally smaller and more dense, and their margins are more sharply defined.

Bronchitis.—Bronchitis when acute gives no characteristic picture. The chronic inflammation appears as an increase in the size and density of the bronchial markings and glands.

Lung Abscess.—Abscesses always occur in the periphery of some portion of the lung. Lateral views are necessary to determine which lobe and bronchus are involved. Lung abscess generally follows: (1) the acute infections; (2) the inspiration of infected material at operation; (3) infected emboli or (4) obstruction of a bronchus. Clinically it is a disease of symptoms rather than signs, therefore, the roentgen examination is of the greatest aid in indicating the site and extent of the process in its early stages.

The lesions are usually single, although they may be multiple. They may occur in either lung field, but show a decided tendency to appear at the bases, particularly the right. They assume the form of irregular areas of increased density, which are most marked at the center, fading out toward the periphery.

Cavity formation is usually present in the areas of infiltration. When filled with fluid they are indistinguishable from the general shadow surrounding them, but the larger cavities become distinct

when partially filled with air, particularly if they contain sufficient fluid to cause a fluid level. If a fluid level is present its surface shifts according to the position of the patient. Small cavities may be entirely overlooked, particularly if filled at the time the examination is made. They can be demonstrated more easily in the

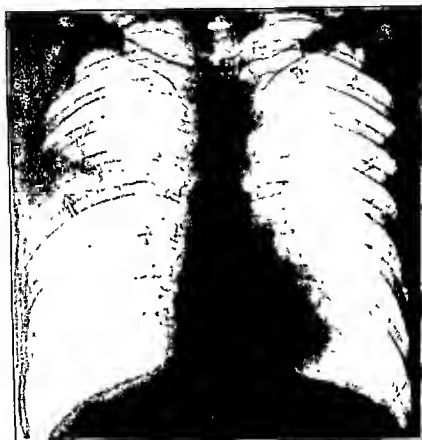


FIG. 178 — Lung abscess. The cavity of the abscess can be seen as an area of diminished density in the center of the dull area in the right chest.

upright position, and the screen examination is likely to be more reliable than the film. Cavities should be carefully looked for, as they are of great diagnostic importance.

If the patient is raising a large amount of sputum, as is frequently the case, films obtained before and after evacuation may show a localized area, the density of which diminishes with evac-

uation. Partially emptied cavities are demonstrated much more easily than cavities that are full.

The bronchial markings distributed to the areas involved are enlarged and coarse, and the hilar shadows are increased in size.

Abscesses may persist for a long time as areas of thickening, or they may heal spontaneously without leaving a trace of their presence on the roentgenogram. Their localization is frequently unsatisfactory to the surgeon, as the zone of pneumonic infiltration surrounding them magnifies the area of involvement. If the cavity of the abscess can be demonstrated, its location is accomplished best by rotating the patient during the screen examination, and, in this way, the point on the chest wall which is nearest to it can be demonstrated. This point should be marked on the patient's skin, and, if possible, it should be the point of approach selected by the surgeon. The distance from this point to the cavity should be indicated also by a second mark on the chest. This mark will be at exactly the point where the shadow of the cavity appears when viewed with the parallel rays of the tube passing through the chest at right angles to the point of approach. This data should be accompanied by a statement as to the presence or absence of involvement of the pleura. If the pleura is adherent, surgical approach is much easier.

Abscesses may be confused with tuberculosis, bronchopneumonia and bronchiectasis. They are rarely mistaken for metastatic malignancy. Their similarity to tuberculosis lies in the occurrence of cavities. In tuberculosis the cavities usually are empty; whereas the cavities of abscesses generally contain some fluid. In tuberculosis there is also further roentgen evidence of the disease, such as the characteristic mottling elsewhere in the lungs, especially at the apices; whereas abscesses are more common at the bases and the apices are clear. Bronchopneumonia may be differentiated from abscess by the fact that it produces a shadow of more uniform density and there is no cavity formation. Bronchiectasis is generally a diffuse process, and the bronchial changes are more extensive than in abscess, although these two conditions may blend into each other at times.

Small multiple abscesses may be mistaken for metastatic malignant disease, but the history and clinical course will determine the diagnosis.

Bronchiectasis.—The chief value of the roentgen examination in this disease lies in determining the location and extent of the disease

and the presence or absence of other lesions. The characteristic picture in a well-advanced case is: (1) the extensive thickening of the lung markings along the course of the larger bronchi; (2) the enlargement of the hilum glands; and (3) the presence of single or multiple areas of increased density in the lung fields near the bronchi, which may show considerable change in films obtained before and after expectoration.

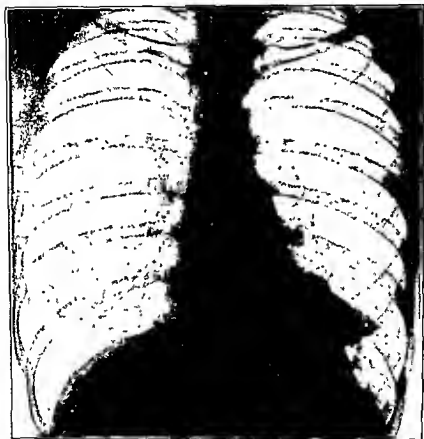


FIG. 179.—Bronchiectasis of left lower lobe, later confirmed by lipiodol injection.

In the early stages the picture is much less characteristic, and depends upon the demonstration of loose, fluffy shadows of the affected bronchi and the infiltrated lung surrounding them. There is an associated emphysema in long-standing cases.

The introduction of an opaque substance (lipiodol) into the bronchi permits of a complete study of the size, shape and distribution of the bronchi. There are two main types of lung involvement, as shown by lipiodol injections. First: Multiple small abscesses scattered through a considerable portion of one or more lobes, with some evidence of bronchial dilatation or deformity. The second form consists of a cylindrical dilatation of the bronchi, which show small buds along their margins.

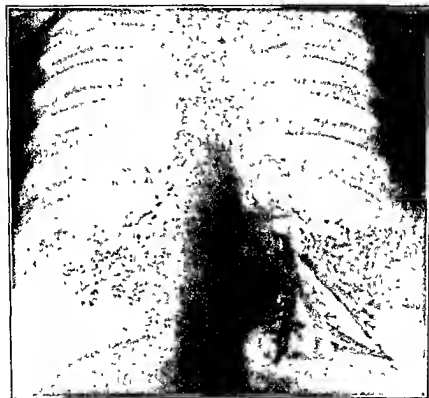


FIG. 180.—Same case as in Fig. 179, exposure made after injection of lipiodol. The dilated bronchi are distinctly visible.

Foreign Bodies.—Foreign bodies may be either opaque, when they are easily recognized, or non-opaque, in which case the diagnosis must rest upon indirect evidence. The presence of a foreign body may cause an area of increased density as the result of: (1) a localized pneumonia surrounding it; (2) abscess formation; or (3) a collapse of one or more lobes due to bronchostenosis. Occasionally

the foreign body may permit air to pass into, but not out of, the affected lung, producing a localized emphysema.

The routine examination for non-opaque foreign bodies should include postero-anterior films taken in inspiration and expiration, as well as lateral films. A survey of the neck and the larynx must not be omitted. Precaution should be taken to obtain films free from motion, otherwise the object may be obscured.



FIG. 181.—Same case as in Fig. 179; lateral view, obtained after lipiodol injection.

The appearance on the film or screen will vary according to the type, size and location of the foreign body, and often only indirect signs are observed. Calcified glands are mistaken sometimes for foreign bodies. When there is obstruction to the entrance of air into a lung or lobe, there is generally some increase in density

throughout the involved area. The diaphragm is high on the side affected, and its respiratory movements are limited. The heart and mediastinal contents are displaced to the affected side. When there is expiratory obstruction only, the affected side is unusually bright, the diaphragm is low and its respiratory movements either limited or absent. If there is displacement of the mediastinal contents it is away from the affected side. This type of case may be more clearly demonstrated by films obtained during full expiration and inspiration.



FIG. 182.—Primary malignant disease of the lung (infiltrative type). There is a small amount of fluid at the base, which obscures the lung markings to some extent.

Gangrene.—The gangrenous lung casts an extensive shadow, which may occupy one entire lung field. Its characteristic features are the presence of large, irregular areas of diminished density, and a general coarse mottling of the shadow. This appearance may be simulated by an expanding lung following a prolonged pneumothorax.

Primary Tumor.—Malignant tumors of the lung are usually carcinomata arising from the bronchial structures. They are unilateral in the early stages, but may spread to the mediastinum and to the opposite lung.

Early metastases to the brain occur frequently, and this lesion may be responsible for the patient seeking medical advice, before the primary tumor has made itself evident. The disease occurs in individuals past middle life and is more common in men than in women. Cough, pain and hemoptysis are the presenting symptoms. The roentgen findings will depend upon the size and location of the tumor and the presence or absence of complicating lesions. The earliest changes are those resulting from obstruction of the bronchi, such as limitation of the respiratory movements of the diaphragm on the affected side, and varying degrees of emphysema in the portion of the lung supplied by the affected bronchus.

As the process extends beyond the point of origin to the regional lymph nodes, dense rounded masses appear at the lung roots. When a bronchus is completely obstructed, the lung collapses beyond the lesion and this collapse is soon followed by consolidation or abscess formation. These tumors also extend along the interlobar septa and in some cases there is a general pleural thickening with the accumulation of fluid in the pleural space. Since the primary tumor is rarely visible and the secondary evidence is often misleading, bronchoscopy and lipiodol injections are to be relied upon for material help in making a diagnosis.

Metastatic Tumors.—Metastatic tumors appear in three forms:

1. There is a progressive enlargement of the hilar shadows. This is unrecognizable in the early stages of the disease, but unmistakable in the later ones, at which time large masses develop at the lung roots. In this form a dense infiltration begins at the hilum and extends outward along the bronchial markings. The affected bronchi become sharply defined, increased in density, and at times enlarged (Fig. 184). As the growth progresses, there is a gradual enlargement of the hilum and mediastinal shadows, and the development of fluid in the pleura. This type is due to direct extension through the lymphatic system.

2. The second and perhaps more common form is that in which the growths take the form of multiple, thin, rounded plaques of variable size with sharp margins, which are scattered throughout the lung fields. These lesions are usually due to cells carried in the blood stream.

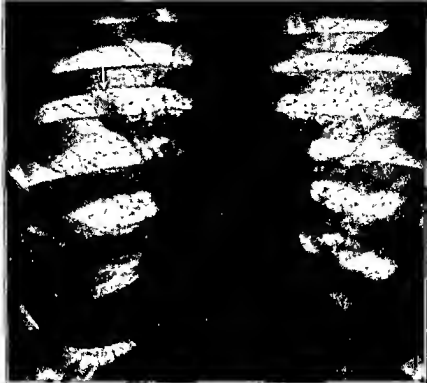
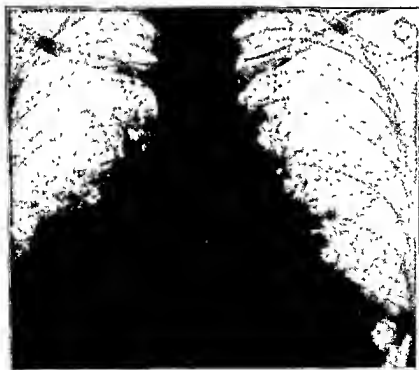


FIG. 183 —Metastatic carcinoma of the lung Primary growth in the stomach.



3. The third form of metastatic disease presents a fine mottling throughout both lung fields, which may suggest miliary tuberculosis. The small areas of increased density, however, are a little larger, more dense and more sharply defined than those of tuberculosis. Lesions of this sort have been seen in metastases from carcinoma of the colon, kidney and thyroid and in chorioepithelioma.

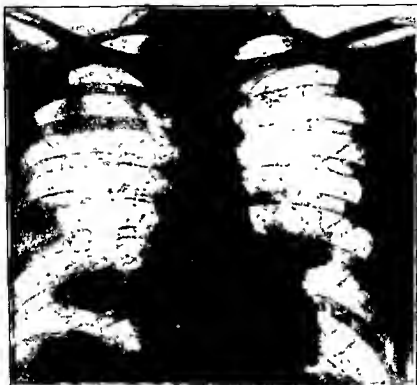


FIG. 185.—Metastatic malignant disease of the lungs. Note the round, sharply defined areas of density in the lung fields.

Single large metastases of the second type cannot always be differentiated from benign tumors. Their location is significant. Benign tumors usually occur in the anterior mediastinum, or along the posterior thoracic wall, while metastases occur within the lung substance. Benign tumors change slowly in size, while the malignant ones usually are of rapid growth.

Syphilis.—There is a difference of opinion on the subject of lung syphilis, but undoubted cases have been reported. Syphilis of the lungs is evidenced in three forms:

1. In the first type, there is a general thickening of all the bronchial markings, particularly toward the hilum, producing a fan-shaped shadow radiating outward into the lung fields.

2. The second type, probably gummata, presents one or more dense, discrete masses in the region of the hilum.

3. The third type occurs as a diffuse shadow which obscures a part of or the entire lung field on one side, which may clear wholly or in part under proper treatment. In this type the lesion is probably in the bronchus, and the picture is the result of bronchial stenosis.



FIG. 150.—Extensive, chronic, inflammatory process involving both lungs, but particularly marked in the left. The clinical findings were those of syphilis.

One characteristic feature of this disease is that the lesions are much more extensive than the condition of the patient would indicate.

Echinococcus Cyst.—*Echinococcus* cysts generally occur in the lower part of the lung field. They are usually unilateral, and single

lesions, but may be bilateral or multiple. The findings in the roentgenogram, or upon the fluoroscopic screen, will depend upon the size and condition of the cyst as well as upon its position. In this disease three distinct appearances have been observed:

1. Closed cysts, which occur as dense, circular or oval, sharply defined areas of increased density within the lung field. The dull area is of even density throughout, and the surrounding lung tissue is normal in appearance. The respiratory movements of the diaphragm are affected only slightly, and the mediastinum is not invaded.

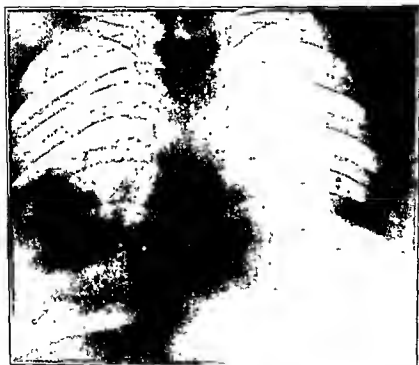


FIG 157.—Multiple echinococcus cysts of the lungs. *a*, Closed cyst; *b*, open cyst ruptured into a bronchus, *c*, open cyst ruptured into the lung structure

2. Open cysts, which may rupture into a bronchus, or into the surrounding lung. In the former, the appearance is the same as in closed cysts, except that the involved area is of diminished instead of increased density, and the picture suggests a large cavity with sharply defined borders.

When rupture occurs within the lung structure, the appearance resembles that of lung abscess. The borders of the lesion are not sharply defined, and the pleura may be involved, producing a marked limitation of the respiratory excursion of the diaphragm on the affected side.

Dermoid Cysts.—Dermoid cysts of the mediastinum may extend into either lung field. They are always connected with the mediastinum usually have a dense wall and may contain calcified material.

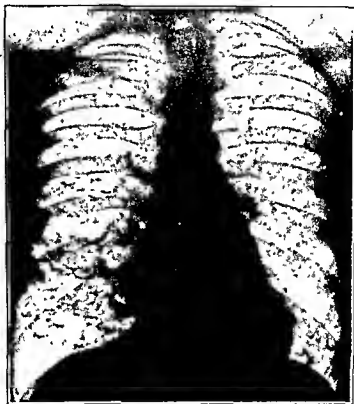


FIG. 148.—Cystic right lung.

Congenital Cysts.—Congenital cysts are usually encountered in children. They may occur in any portion of the lung and are particularly common in accessory lobes. Their appearance is that of multiple small bubbles in the lung or large pocketed cavities suggesting a pneumothorax with adhesions. Their presence may not be suspected until infection develops and the picture then suggests bronchiectasis.

A single cyst may be large enough to occupy an entire half of the thorax or even extend across the mid-line.

Actinomycosis.—Actinomycosis generally occurs in the form of a lung abscess, and its roentgenological appearance is not characteristic. It runs a chronic course with continuous high fever. As the disease progresses, the chest wall may become involved, and the film frequently presents an area of destruction in the overlying ribs. This complication does not occur in other infections.



FIG. 189 — Actinomycosis of the lungs. The changes are most marked at the right descending bronchus, simulating bronchiectasis.

Psittacosis.—The characteristic findings in this disease are small, round spots of pneumonic infiltration which usually appear first in the left lower lobe. Within a few days the process spreads to the opposite side and then is indistinguishable from the usual picture of a pneumonia.

Silicosis (Pneumoconiosis).—The usual chronic form of this disease begins with a deposit of dust in the lymphatic system of the

lungs producing an enlargement and increased density of both hilar regions. Later on there is a slight haziness of the lung about the hilum associated with a general increase in the bronchial markings due to congestion and fibrosis about the lymphatics. There is no involvement of the lung parenchyma at this stage of the disease, which may last for several years. With continued exposure, the second stage develops in which fibrous nodules, 1 to 5 mm. in diameter, appear in the parenchyma of the lung, usually somewhat



FIG 190.—Pneumonoconiosis.

symmetrically distributed. These nodules increase in size and form confluent masses which may be quite large. The apices and bases are usually spared but not necessarily so. In the third stage there is a continued increase in the nodular masses and pleural thickening due to fibrosis about the subpleural lymphatics. The final picture is either that of cardiac failure (due to interference with the pulmonary circulation), or the development of tuberculosis. In the latter case there may be considerable confusion in the diag-

nosis. If there have been no previous films of the patient's chest, it may be very difficult, after a frank tuberculosis with cavitation has developed in such an individual, to determine how much of the picture is fibrous tuberculosis and how much is a preëxisting silicosis.

The course of the disease varies with the amount of exposure and the chemical composition of the dust. In the acute form found in workers in abrasive soap factories, the disease may be fatal in a few months. The earlier changes described above are not seen and a massive involvement of both lungs occurs very early. It is certain that the disease runs a more rapid course in the presence of active tuberculosis or syphilis.

Postoperative Pulmonary Complications.—In order of their frequency these complications are: (1) pneumonia; (2) abscess; (3) massive collapse; and (4) infarcts.

Both pneumonia and abscess have been described, and therefore will not be further discussed.

Massive collapse or atelectasis is probably due to several causes, among which are partial or complete inhibition of the diaphragm, and the accumulation of secretion in the bronchi. The lesion is observed after trauma to the chest or abdomen, and following abdominal operations.

It may be limited to a single lobe or involve several lobes on the same or both sides. When the shadow is unilateral there is a sharply defined dullness corresponding to the area of one or more lobes, a high fixed diaphragm on the affected side, a displacement of the heart and mediastinal contents to the affected side, and a narrowing of the intercostal space. When both lower lobes are involved the diaphragm is high on both sides. The heart and mediastinum are not displaced and narrowing of the intercostal spaces is not apparent. Usually there is a soft mottled dullness in the lower portions of both lungs and in the hilar regions, which is often mistaken for bronchopneumonia. The condition may clear in a day or so or may become chronic. The treatment consists of postural drainage or bronchoscopy for the removal of obstructing secretion. As soon as the obstruction is relieved, the lung rapidly expands to the normal size. If it is not relieved, pneumonia followed by abscess formation is not uncommon, or the involved area may remain permanently collapsed.

Certain shadows seen at the right border of the heart between the fourth rib and the diaphragm, in the antero-posterior view, represent collapsed right middle lobes. The lateral view is necessary

to make the diagnosis. These shadows are triangular, oval or rectangular. They lie in the anterior part of the chest, extending forward from the lung root. Care must be taken not to confuse these shadows with an interlobar collection of fluid. After collapse the size, shape and position of the middle lobe are determined by the amount of emphysema in the adjoining lobes, and the presence of pleural adhesions about it.

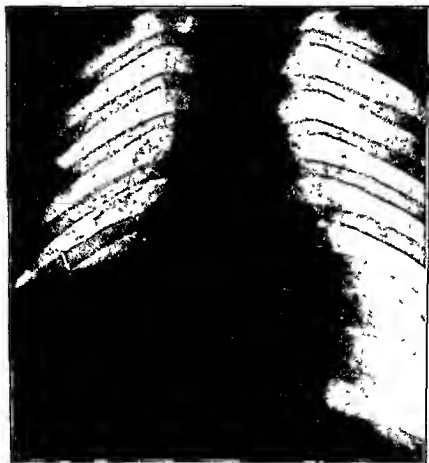


FIG. 191.—“Massive collapse” of the lung. The process involves the right lower lobe.

Infarcts.—Pulmonary infarcts produce hazy areas of increased density, either single or multiple. When seen in profile they are triangular in shape with the apex of the triangle toward the hilum.

There is no displacement of the heart or mediastinum, and, as a rule, there is no interference with the respiratory movements of the diaphragm.

By means of the roentgen examination alone it is not possible to differentiate the lesion from that of pneumonia.

The Pleura.—The normal pleura casts no appreciable shadow, and is therefore not visible on the film or screen. When diseased, it may prevent complete expansion of the lung over the involved area, and appear on the film or screen as an area of increased density, through which the ribs, as a rule, are visible. The respi-



FIG. 192.—Collapsed middle lobe. Its high position was due to pleural adhesions.

ratory movements of the diaphragm on the affected side are limited, and the costo-phrenic sinus may be obliterated. A thin, curved, white line extending across the right chest, with its convexity upward, is seen occasionally as the end-result of an interlobar pleurisy. Adhesions, when visible, appear as strands of increased density.

There has been considerable discussion regarding the significance of thin, annular shadows in various portions of the lung field, which suggest cavity formation. There is no doubt that some of these represent local pleural thickening. Stereoscopic and lateral films will help in differentiating them from cavities.



FIG. 193.—Lateral view of collapsed middle lobe. This appearance must be differentiated from an interlobar effusion or thickened pleura.

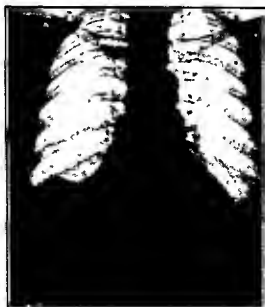


FIG. 194 —Collapsed middle lobe. Same case, anteroposterior view.

Pleural Exudate.—Fluid in the pleural space generally produces a shadow of extreme density at the base, which obscures the ribs and diaphragm. The superior margin of this shadow curves upward toward the chest wall in the axilla, unless pneumothorax is present, in which event it will show a fluid level that changes with a change in the position of the patient. In the prone position, the shadow is uniform throughout the chest, and often resembles



FIG. 195.—Pleurisy, with effusion at the left base. Note the position of the shadow in the axillary border, and the displacement of the heart to the right.

that of a thickened pleura or pneumonia. If the effusion is extensive, there is generally a displacement of the heart and great vessels. The apex of the lung is generally clear. At times fluid may appear as a zone of increased density about the periphery of the entire lung.

Encapsulated Fluid.—Encapsulated fluid produces a sharply defined shadow in contact with the pleura. It is most common at

the base, along the axillary border and between the lobes. When the collection of fluid is between the lung and the diaphragm it may simulate subdiaphragmatic abscess. There may be more than one collection of fluid, or a single collection may be divided into one or more pockets. These pockets may not become visible until after an attempt is made at drainage.



FIG. 196.—Lateral view of a normal lung. The shadow resembling a collapsed middle lobe is due to the overlapping of a high right diaphragm and the heart shadow.

The roentgen examination in these cases should always include localization under fluoroscopic observation, of postero-anterior and lateral films. It is of considerable importance to the surgeon that the lowest point of the pocket be located. In order to obtain this point the patient should be placed on his side, with the area to be examined uppermost and the hips slightly elevated which will permit any air which may be present in the pocket to outline the lowest point. In this way, the relation of the floor of the pocket to the chest wall can be demonstrated.

There is no difference in the density of the shadow cast by an

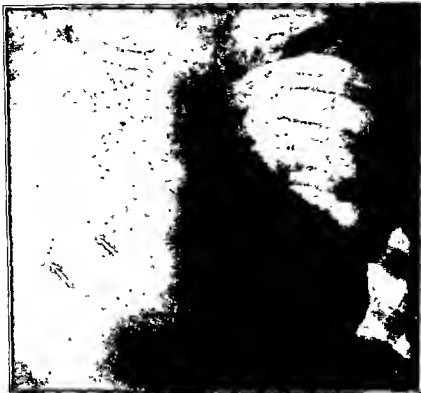


FIG. 197 —Encapsulated empyema. The process is between the lower and middle lobes, as indicated by the arrows

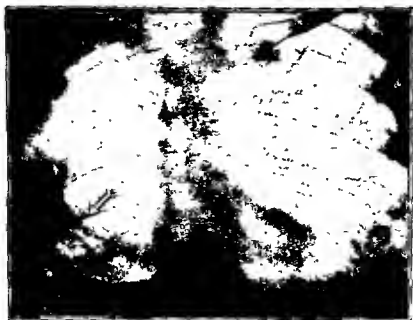


FIG. 198.—Old empyema, with calcification in the right pleura.

exudate or effusion and that cast by pus. The shape and position of the shadow, however, may be of considerable aid in the diagnosis.

Simple fluids are rarely encapsulated, and, for this reason, are seen in the most dependent portions of the chest, usually the costophrenic angles, from which they extend upward and inward, the axillary border always remaining the highest point and the upper



FIG. 199.—Pneumothorax, with partial collapse of the right lung. Note the absence of lung markings and the increased radiability at the periphery.

border maintaining its curved form. An *empyema* may form in the same manner, but as it is frequently encapsulated the curve of the upper margin may be absent. In differentiating between lobar and interlobar shadows, films made with a high tube position, so that the incident rays enter the patient's upper back at an angle of 30 degrees from the horizontal, may be useful.

Pneumothorax.—Pneumothorax is characterized by the presence of an area of greatly increased radiability in the periphery of the lung field in which the lung markings are absent. Its borders are sharply defined, and consist of the walls of the chest cavity and the margins of the compressed lung.

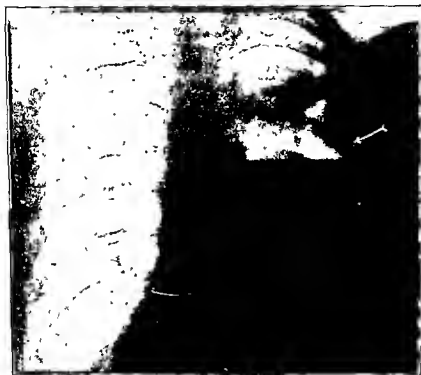


FIG. 200.—Hydropneumothorax (patient in the upright position). The fluid level is well shown at about the middle of the left chest.

When the pneumothorax is complete, and no adhesions are present, the lung collapses and appears as a lobulated mass at the hilum, in which, as a rule, only a suggestion of lung markings can be seen. In the presence of pleural adhesions the collapse is incomplete. The shadow of the pneumothorax may be divided by bands giving it a sacculated appearance, or the area of pneumothorax and lung tissue may overlap each other. A small, localized pneumothorax appears as an area of somewhat increased radiability overlaid by normal lung markings, and is difficult to detect unless observed in profile. Large emphysematous blebs must not be mistaken for localized pneumothorax.

Films taken at the end of the expiratory phase are necessary to demonstrate a pneumothorax in some cases and are always desirable.

Calcifications frequently appear in the pleura in the form of ragged, dense plaques or lines. They may occur in any part of the lung field, but are seen most frequently along the axillary border, or in the region of the lower lobes. The respiratory movements of the diaphragm on the affected side are usually limited, and the position of the diaphragm may be high. This condition must not be confused with calcification of the costal cartilages, which is of no significance.

Malignant disease of the pleura produces a shadow which suggests a small effusion or greatly thickened pleura, and the diagnosis can seldom be made from the roentgenological evidence alone. It is usually accompanied by an effusion. Endothelioma of the pleura appears first as a localized thickening of the pleura, usually in the upper portion of the chest, and slowly involves the entire pleura on the affected side. A characteristic finding is a retraction of the ribs over the growth.

Fluid in the pleural space, or disease of the pleura, may be confused with a pathological process in the lung structure. This is especially true if the examination is made in only one position; but if the patient is rotated during the fluoroscopic observation, and lateral films are obtained, the true location of the process can generally be demonstrated.

Radiation Fibrosis.—Following massive doses of heavily filtered radiation to the chest wall, a fibrosis and partial atelectasis develops in the irradiated area of the lung. It appears about six or eight weeks after the treatment and is accompanied by a severe dry, hacking cough and marked shortness of breath.

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CHAPTER IX.

THE GASTRO-INTESTINAL TRACT.

Technic.—An adequate examination of the gastro-intestinal tract should include both a fluoroscopic observation and a series of films. The fluoroscopic observation reveals information relating to mobility and function which cannot be obtained from the films alone, whereas the films present detail of structure which may be overlooked on the screen. These combined methods are, therefore, complementary.

The value of fluoroscopy depends upon the skill and experience of the examiner, and it is obvious that he should be well trained. The secret of success in this work is thoroughness, which is more essential in this particular examination than in any other field of roentgenology. Examinations should frequently be repeated, and the patient adequately studied, before an opinion is rendered. A brief knowledge of the clinical history is essential, and this should be obtained before the roentgen examination.

Special care should be used in selecting the barium sulphate. The preparation sold by the large drug houses for internal use is free from all impurities, and absolutely harmless. The commercial product, on the other hand, may contain poisonous impurities.

For a study of the esophagus and the upper gastro-intestinal tract, the patient should report in the morning, having taken no food or liquid since the previous evening meal. The patient is placed in position for the fluoroscopic examination and given a swallow of a fairly thick barium mixture. Its progress is watched through the esophagus and stomach. Another swallow of barium is given and the stomach and duodenum are carefully palpated to outline the pattern of the mucosa. This study of the mucosa may be conducted with the patient upright or better in both the upright and prone positions. Variations from the normal are noted and recorded on spot films. The patient then drinks the remainder of an 8-ounce meal, which outlines the entire stomach and duodenum. Before the study is concluded, the second and third portions of the duodenum are carefully observed and large films are made for record

purposes in the prone position. The patient returns in six hours for an examination of the ileocecal region. In some clinics a double meal is employed. The patient takes a standard barium meal with a carbohydrate breakfast and reports for examination six hours later, having taken no food in the interval. At this examination the upper abdomen is inspected for the presence of a residue in the stomach, duodenum or upper intestinal tract, and the ileocecal region carefully studied. A second meal is given and the same procedure carried out as with the single meal.

In some cases it may be desirable to have a nine-hour observation to check the emptying time of the small intestine. In this case the second meal is not administered until after the nine-hour observation. The patient is seen again at twenty-four hours after the first meal for a study of the colon, noting its position, tone, mobility and motility. To complete the examination, the patient should return for an opaque enema after catharsis. If the history suggests that there is a lesion in the colon, the method of examination may be reversed and the enema given first. The barium enema should be given under fluoroscopic observation, with the patient prone, so that the sigmoid loop falls forward and is flattened against the anterior abdominal wall. By this maneuver small lesions in the sigmoid may be visualized which would be obscured by the superimposed shadows of sigmoid and rectum, if the patient were supine.

The enema should be given slowly to permit detailed study of the filling of the bowel. When the enema has reached the upper sigmoid the patient should be turned on his back and the entire colon palpated as it fills to bring out the mucosal pattern and to determine the presence or absence of fixation or points of tenderness. Spot films may be taken of any unusual findings. The patient should be rotated slightly both to the right and left, to uncover the loops of intestine in the pelvis and at the flexures. When the colon is completely filled large films are made covering the entire colon. The patient evacuates the enema after which the fluoroscopic examination is repeated and another large film made.

THE ESOPHAGUS.

The esophagus is well outlined by the ordinary barium meal. For more detailed observation, particularly in cases of suspected new growth, a thick mixture of barium sulphate is more valuable.

In the right oblique diameter, the normal esophagus can be seen

clearly throughout its course. It presents an indentation on the anterior border at the level of the arch of the aorta, a second slight indentation, due to the left bronchus, and then curves backward behind the heart, to enter the stomach. In its lower course it is an excellent guide to the outline and position of the posterior wall of the heart. It is smooth in outline, and the opaque mass passes readily through it with only a momentary pause at the aortic arch, and a slight delay at the cardia. Regurgitation of the meal through the cardia with the patient prone or supine may occur under normal conditions, but it is more frequent in gall-bladder disease and in carcinoma of the stomach.

The normal esophagus rarely shows peristalsis. When present it is usually indefinite and broken. With obstruction from any cause, however, waves of varying depth may be observed in the esophagus above the obstruction. In advanced cases it may be reversed.

Changes in Position.—The esophagus may be displaced by: (1) mediastinal tumors; (2) aneurysms; (3) effusion; (4) fibrosis of the lung; (5) diseases of the spine; (6) developmental anomalies. The displacement is almost invariably due to extrinsic causes. Lesions within the esophagus rarely cause displacement, although they may produce marked dilatation and tortuosity. The position of the esophagus may be of considerable value in determining the location of a mediastinal tumor.

Changes in Outline.—The outline of the normal esophagus is smooth. Irregularities in outline are generally due to tumors, varices, spasm or adhesions.

Annular deformities are due to carcinoma or stricture. Smooth, rounded depressions in outline result from the pressure of extrinsic tumors or adjacent organs. Multiple irregularities and constrictions are generally caused by the ulceration and scar-tissue formation due to the swallowing of corrosive substances. Congenital atresias are encountered in infants. One end of the esophagus usually connects with the trachea or bronchus.

A projection of the barium shadow beyond the normal outline of the esophagus is present in diverticula and fistulae. Ulcers do occur occasionally in the lower esophagus but they rarely show a crater projecting beyond the lumen.

Changes in Size.—The normal esophagus varies considerably in size during an observation. The walls are flexible and dilate in proportion to the size of the bolus passing through it. Dilatation

of varying degree occurs above obstructions. As a general rule, the lower the obstruction and the longer the duration, the greater will be the dilatation. For this reason benign lesions generally show a greater degree of dilatation than malignant ones.



FIG. 201.—Diverticula of the esophagus. Note that the barium mass lies to the side and spills over into the esophagus at the point indicated by the arrow.

Congenital Anomalies.—The esophagus may be absent or partially or completely double. There may be a stenosis in the lower portion. Fistulae may occur into the trachea with either end of the esophagus ending in a blind pouch. When anomalies of the aorta are present the upper esophagus may lie anterior to the arch of the aorta or be displaced either to the right or left.

Diverticula.—Diverticula may appear in any portion of the esophagus, but most commonly in the upper and lower ends. They appear as rounded pouches which overflow into the esophagus. It may be necessary to view the patient from several angles to bring this opening into profile. The pockets remain partially filled after the remainder of the meal has passed on. A liquid meal is preferable, as solid masses may not enter them.

Fistulae.—In rare cases the meal may be seen to enter a descending bronchus through a broneho-esophageal fistula resulting from an ulcerative process involving the bronchus or esophagus due either to carcinoma or infection.



FIG. 202 --Cardiospasm. Note the extension of the esophagus to the right, and the smooth, round borders of the barium shadow.

Cardiospasm.—The esophagus may be greatly dilated in cardiospasm. A glass of hot water will sometimes relax the spasm, and permit part or all of the meal to enter the stomach. There is no apparent irregularity of outline, and the shadow ends at the cardia

in a smooth, funnel-shaped mass. Peristalsis becomes visible, and it may be deep, irregular, or at times reversed. The dilatation of the esophagus occurring as a result of cardio-spasm may cause the margin of the esophagus to extend into the lung field on the right side. In these cases there may be a delay of the meal above the cardia for hours or days.



FIG. 203.—Cardio-spasm showing dilated, gas-filled esophagus, as indicated by the arrows.

Tumors of the cardia of sufficient extent to cause obstruction can generally be recognized by irregularities in the outline of the barium mass in the lower esophagus or stomach. They do not produce the extreme dilatation of cardio-spasm.

Varices.—Esophageal varices usually occur as the result of obstruction in the portal system but may be the only lesion demonstrable. They are best seen with the patient in the supine position after swallowing a small amount of a viscous mixture. The normal

mucosal pattern is replaced by tortuous, worm-like bands of diminished density running longitudinally, which are usually most marked in the lower third of the esophagus. They may vary in size, with changes in the intrathoracic pressure. They do not show pulsation except as it is transmitted from the aorta. Demonstration of these lesions is important for they are a frequent cause of hemorrhage, and their presence may lead to the diagnosis of an unsuspected cirrhosis of the liver.



FIG. 201.—Carcinoma of the esophagus. Note the characteristic annular ragged, mottled shadow.

Benign Stricture.—Constrictions of the esophagus of non-malignant origin are comparatively rare. They may occur in any part of the esophagus, but are observed, as a rule, in the middle and lower thirds. They are frequently multiple, and there is generally a marked

dilatation above the point of constriction. Their outline is smooth and frequently cone-shaped, with the opening at the apex of the cone. The esophagus directly below the stricture is normal in size and contour. Peristalsis is usually evident above the constriction.

Constrictions may be differentiated from spasm by their constancy, from diverticula by the fact that the opening is at the lowest point instead of at the side, and from carcinoma by their smooth outline, degree of dilatation and the fact that they are so frequently multiple.

Tumors of the Esophagus.—Carcinoma is the most common lesion occurring in the esophagus. Like carcinoma elsewhere, it is a disease of late adult life, and the onset is insidious. The earliest evidence of its presence is local spasm or deformity of the mucosal pattern. When ulceration has occurred the findings become characteristic, and can generally be demonstrated by either the liquid or the semi-solid meal. If the latter is used, care should be taken to have the esophagus clear of all solid particles, as they may simulate the mottled shadow of carcinoma. The common location is in the middle third or lower end, but the lesion may appear at any point.

The outline of the esophagus presents a constant annular, mottled deformity of varying extent, with ragged edges. There is little, if any, dilatation of the esophagus above, and the lesion is never multiple. Peristalsis may be visible, but it is less likely to be observed in the malignant lesions than in the benign type. The patient may complain of pain during the examination, and may have considerable difficulty in retaining the mixture within the esophagus, especially if the lesion is high. Benign lesions do not produce this reaction.

Esophageal spasm is the most frequent cause of mistake in diagnosis, and should be ruled out by repeated examination.

Other tumors are rare but leiomyomata and myxomata have been observed.

THE STOMACH.

The normal stomach hangs more or less centrally in the abdominal cavity with the lesser curvature at a variable distance above the level of the iliac crests.

The shape and position of the stomach are determined by: (1) the habitus of the individual; (2) the tone of the gastric wall; (3) the tension of the abdominal muscles; (4) the pressure of adjacent organs; and (5) the amount of the barium meal administered.

Thin individuals with a narrow costal arch have long central stomachs, which hang low in the pelvis. In broad, fat individuals with a wide costal arch, and in individuals of strong muscular development, the stomach is high and transverse. In asthenic states the stomach is low, and owing to the lack of tone, the meal settles in the lower pole, causing the walls of the body to



FIG. 205.—Mucosal pattern of normal stomach.

collapse. In the prone position, the stomach swings up under the liver, lying more transversely than when in the upright position. When the stomach is empty its walls are in apposition, except at the cardia, which is dilated by the gas bubble. As the stomach fills, the meal collects in a funnel-shaped mass below the gas bubble, and gradually distends the body and antrum. In atonic stomachs, the meal passes rapidly to the lower pole, which enlarges out of

proportion to the body. Some individuals have a large posterior extension of the cardiac pouch which retains a fluid level of its own in the upright position.

The outline is smooth, except for indentations due to peristalsis, and for a variable amount of irregularity on the greater curvature due to folds in the mucous membrane and pressure from the colon and spleen. Small, transient indentations occur on the margins of the antrum near the pylorus. The rugæ show through the barium mass whenever the walls are approximated. With the first swallow of barium the rugæ below the gas bubble are visualized and next those in the body and pyloric end of the stomach. The barium is easily spread over both walls by palpation and ordinarily a small amount squeezes through the pylorus to outline the folds in the first portion of the duodenum. Rugæ represent folds of mucosa and submucosa. Changes in either one will produce alterations in the relief pattern. They vary in size and distribution, being in general parallel to the long axis along the lesser curvature and on the anterior wall, more tortuous on the greater curvature and posterior wall. At times it may be impossible to demonstrate them in the antrum. They may be increased in size in inflammatory conditions, hypertrophic gastritis and lymphomatosis. Diminution in size is of no significance. They are locally absent about tumors. In the region of chronic ulcers they are distorted, with a tendency to produce stellate patterns due to scar tissue formation.

Normal peristalsis begins at about the middle of the lesser curvature, with a corresponding shallow depression on the greater curvature. The waves travel toward the pylorus without interruption. They become progressively deeper as they pass forward, and may bisect the barium at the upper limits of the antrum. If the pylorus opens, the antrum contracts and forces its contents into the duodenum. If the antrum does not contract, the waves move to the pylorus. Peristaltic waves occur at intervals of about twenty seconds, varying with the patient and the kind of meal administered. Ordinarily no more than two or three waves are visible on a stomach at the same time. They are affected strongly by mental states, being increased by anger and inhibited by fear and nausea. They are also increased in number and depth with the patient in the prone position.

Changes in Size.—The stomach is increased in size when dilatation has occurred as a result of pyloric obstruction, and in all conditions where there is a general loss of muscular tone. It is diminished in size as the result of: (1) increase in tone due to strong, muscular

development; (2) spasm, either local or reflex; and (3) involvement of the wall by ulcer, carcinoma, adhesions, syphilis or linitis plastica.

Changes in Position.—The stomach is displaced upward and to the right (1) when there are adhesions resulting from gall-bladder disease; (2) accumulation of a large amount of gas in the splenic flexure; and (3) tumors in the left upper quadrant. In some cases of appendiceal disease, or adhesions, the lower pole is swung over toward the right iliac fossa. The stomach may be displaced and rotated upward on its long axis in cases of adhesions to the anterior abdom-



FIG. 206.—A, penetrating ulcer of the lesser curvature, B, ulcer of the duodenum.

inal wall. General gaseous distention of the intestine, or fluid in the peritoneal cavity, crowds the stomach upward against the liver.

Displacement of the stomach downward (ptosis) is of no importance unless accompanied by definite clinical evidence of abnormal function. The stomach may be displaced downward and to the left by enlargement of the liver, or tumors in the right upper quadrant. In pyloric obstruction when dilatation has occurred, the stomach shadow often appears farther to the right than normal, but this is due to the dilatation of the antrum, and is not, therefore, a true displacement of the entire stomach. At times the cardiac end of the stomach is found above the diaphragm as the result of a congenital or traumatic hernia. It is usually best seen with the patient supine,

Changes in Outline.—Changes in the outline of the stomach occur as the result of. (1) spasm, (2) gastric lesions; (3) defects due to extrinsic causes, such as pressure from tumors; and (4) solid materials in the stomach, such as food-masses, foreign bodies, hair-balls, etc.

1. *Changes in the Outline of the Stomach due to Spasm.*—Localized spasm produces narrow contractions which may be near the pylorus, or in the upper portion of the body of the stomach, at which point the greater curvature is drawn in toward the lesser over a space of a few millimeters. These spasms may be reflex, or due to the irritation of a small ulcer or new growth at this level. Spasm in some cases may be extensive, obliterating the entire antrum, for example. Like the localized spasm, it may be entirely reflex, or due to an associated lesion of the stomach wall.

The differentiation of functional and organic spasm is often most difficult. Functional spasm is generally transitory, so that repeated examinations will often settle the question. Antispasmodics, such as belladonna and papaverin, may be employed, but the results will not be conclusive, owing to the fact that at times they will relax the spasm associated with a lesion of the wall as readily as that due to extrinsic causes. The demonstration of normal mucosa in the affected region is strong evidence against an intrinsic lesion.

2. *Changes in the Outline of the Stomach Due to Gastric Lesions.*—Under this heading are: (a) the contracted, rigid, smooth lesser curvatures with absence of peristalsis, as observed in ulcer and carcinoma; (b) the presence of a penetrating or perforating ulcer projecting from the gastric outline on the lesser curvature or posterior wall, and (c) the marked irregularities of carcinoma which vary according to the size, shape and position of the tumor. These deformities, as a general rule, are either annular or irregular; if the latter, they are due to the presence of nodular masses invading the barium mixture, thereby producing ragged holes or markings resembling finger prints.

Other deformities of outline are caused by: (a) local contractions due to ulcer and its associated spasm; (b) extensive defects produced by lues, suggesting ulcer or carcinoma; (c) scar-tissue contraction in the gastric wall, producing the so-called "hour-glass" stomach; (d) polyps which cause round defects in the barium shadow. They may be single or multiple or take the form of irregular defects along the greater curvature.

3. *Changes in the Outline of the Stomach Due to Extrinsic Causes.*—There are defects in the outline of the stomach due to extrinsic

causes, such as pressure from adjacent organs or tumors, as, for example, an enlarged gall-bladder which may produce a rounded depression in the region of the pylorus, or pancreatic tumors which may cause an irregularity of the greater or lesser curvature. These defects in outline are not constant in all positions of the patient. An enlarged liver may cause a defect in the antrum by compressing it against the spine. In films obtained with the patient in the prone position, it will be observed that the pressure of the spine against the abdominal wall generally produces a break in the barium shadow overlying it. Thin individuals often show an indentation on the greater curvature due to pressure from the left costal cartilages.

Perigastric adhesions, particularly in the region of the pyloric end of the stomach, may produce ragged defects in outline suggestive of carcinoma, but, as a rule, they are not constant in all positions.

4. *Changes in the Outline of the Stomach Due to Solid Materials in the Stomach.*—Any solid material in the stomach, such as food-masses, foreign bodies, hair-balls and the like may cause defects in the barium mass which resemble malignant disease. However, these irregularities shift with change in the position of the patient, and there is no interference with peristalsis.

Papillomata produce irregularities of outline similar to those caused by large foreign bodies, but in papillomata there is little displacement of the defects with change in the position of the patient, and they are constant upon repeated examinations. Peristalsis is not interfered with.

Changes in Peristalsis.—Increase in the depth and speed of peristaltic waves may be due to reflex causes, or it may be compensatory to a diseased pylorus.

In the early stages of pyloric obstruction, the waves are deep and vigorous. They may divide the stomach into segments, giving it the appearance of a row of balls. In this condition the waves also begin higher, and the number of waves visible at one time are increased.

Peristaltic waves are absent in: (1) achylia; (2) pyloric stenosis after extreme dilatation has occurred; (3) infiltration of the gastric wall; or (4) nausea, fear and faintness. When the stomach is greatly dilated secondary to pyloric stenosis, periods of exaggerated peristalsis alternate with complete cessation of activity.

Peristaltic waves become irregular when they encounter bands of adhesions or areas of infiltration in the gastric wall. In certain functional diseases also they are irregular. Peristaltic waves may

be reversed in carcinoma and during vomiting and the gastric crises of tabes.

Motility.—In an adult the emptying-time of the normal stomach varies from three to six hours, depending upon its tone and functional activity, and the amount and composition of the meal. In children up to six years of age the emptying-time is about half that of the adult and the same is true of their intestinal motility. Rapid emptying of the stomach in an adult suggests: (1) achylia; (2) early duodenal ulcer; or (3) an incompetent pylorus.

If there is a definite residue (one-fourth of the meal) beyond the six-hour period, and the patient has taken no food in the interim, the conditions to be considered are: (1) a lesion within the stomach; (2) a spasm of the pylorus from extrinsic causes, such as duodenal ulcer, disease of the appendix or gall-bladder; or (3) an obstruction in the intestine below the stomach. In some instances delay may be caused by acute illness, general atony of the gastro-intestinal tract and the action of drugs such as morphine.

DISEASES OF THE STOMACH.

Carcinoma.—The onset of carcinoma is insidious and usually the disease is well established when the patient appears for examination.

The characteristic findings are: (1) irregularities of outline; (2) alterations in the mucosal pattern; (3) sluggish, irregular, reversed or absent peristalsis; (4) esophageal or gastric stasis; (5) early gastric emptying; and (6) loss of flexibility of the stomach wall. The appearance varies considerably both with the type of growth and with its location.

Carcinoma of the cardia is often difficult to visualize. In these cases, it is well to observe the first mouthfuls of barium entering the stomach. It will be seen that the jet is irregular instead of smooth, and there may be delay at the cardia. There will also be rigidity and deformity of the fundus, which does not change upon deep inspiration. This observation should be made with the patient lying on his back.

Large growths in the body and antrum of the stomach are generally characteristic. There is a ragged, angular defect which is constant at all times and in all positions. If the tumor is palpable, it coincides with the defect. Peristalsis is absent in the region of the growth, and may be either irregular, sluggish or reversed elsewhere. Stasis is generally present but not large in amount.

Carcinoma of the stomach is to be differentiated from benign ulcer, lues, adhesions and extragastric tumors. Typical ulcers and carcinomata are differentiated easily, but the borderline cases are difficult to identify.

Carcinomatous ulcer, like the benign type, may be limited to one wall, and present a rigid area of infiltration from which the pocket of a crater projects. However, the crater is generally larger in carcinoma, and peristalsis is either diminished or irregular, whereas in ulcer it is likely to be increased. Stasis may occur in both conditions, but is, perhaps, more common in ulcer. Spasm and incisura are also more common in ulcer.



FIG. 207.—Carcinoma of the pyloric end of the stomach and lower curvature.

The location of the lesion is of great importance. Benign ulcerations are rare in the prepyloric region and never occur on the greater curvature or in the cardia.

There is a difference in the appearance of the relief pattern about the two lesions. In carcinoma the rugæ stop abruptly a short distance from the crater and their general position is not disturbed, whereas in benign ulcers the rugæ radiate from the crater without interruption.

In lues the deformity, while resembling that of carcinoma, is generally more irregular, and the patient's condition is much better than would be expected with a carcinoma of similar extent. The defect is out of proportion to the symptoms.

The defects in adhesions and extragastric tumors are generally not constant in all positions, and stasis is usually absent.



FIG. 208.—Perforating ulcer of the lesser curvature. Note the infiltration about the crater

Diffuse infiltration of the stomach wall occurs in scirrhus carcinoma, lues and linitis plastica. The signs of infiltration are a smooth rigid outline with absence of peristalsis, and, as a rule, a contracted, rapidly-emptying stomach.

Pyloric Carcinoma.—In well-established cases, there is a definite, funnel-shaped defect over which there is absence of peristalsis. If the pyloric ring is involved it often becomes rigid, and the stomach may empty rapidly. Dilatation is rarely pre-ent. In early cases

this funnel-shaped defect may be much larger than the actual lesion, as the result of associated spasm. For this reason, and the fact that the roentgen-ray examination does not reveal evidence regarding the presence or absence of extension of the growth to the regional lymph glands, it is unwise to predict from the roentgenological findings alone the extent of the lesion in a given case of gastric carcinoma.

Ulcer.—The recognition of an ulcer depends upon: (1) the presence of a crater, which can be filled with barium and visualized or brought into profile by palpation; (2) the characteristic deformity of the mucosal pattern; (3) localized tenderness; (4) the presence of associated spasm; (5) increase in peristalsis; and (6) the presence of stasis. In some cases spasm and stasis are absent; stasis becomes increasingly important the closer the lesion lies to the pyloric ring. If it involves the ring and there is no stasis the lesion is probably due to carcinoma or adhesions. Benign ulcers involving the pylorus are usually associated with stasis.

Ulcers may be grouped as follows: (1) mucosal; (2) indurative; (3) penetrating; and (4) perforating.

1. The mucosal type is generally indicated by a small fleck of barium at the site of the lesion, and may or may not be accompanied by hyperperistalsis and stasis. There is often no associated enlargement of the rugae about the lesion. They are easily overlooked.

2. In the indurative form, there is an area of infiltration usually seen on the lesser curvature, which, if extensive, may cause considerable shortening of this curvature. There is a break in peristalsis at the site of the lesion. A crater cannot be demonstrated but a characteristic stellate mucosal pattern is present. Spasm is not present, as a rule. When present it takes the form of local incisure opposite the active edges. Such ulcers after a time may cause irregularity of the greater curvature from contraction of scar tissue, which extends out, to envelop the body of the stomach.

3. Penetrating ulcers have all the signs of the indurative type roentgenologically, but in addition there will be seen a mass of barium projecting from the rigid area corresponding in size and shape with the crater of the lesion. Although surgically they may be located on the posterior wall, they are generally observed on the lesser curvature during the roentgen examination. In order to visualize these lesions adequately, observation in the lateral position is necessary. These protrusions are to be differentiated from the duodeno-jejunal flexure, which often projects just above the lesser curvature. Rotating the patient and requesting him to

take a deep breath, will enable the examiner to determine whether the mass is actually projecting from the gastric shadow, or independent of it.

4. In perforating ulcer, there is, in addition to the signs of a penetrating ulcer, the presence of a gas bubble outside the stomach wall above the barium in the crater.



FIG. 209.—Roentgenogram, showing lues of the stomach.

Frequently a spontaneous pneumoperitoneum is the earliest evidence of acute perforation. Its detection requires only a brief fluoroscopic examination, which can be carried out without preparation and with little disturbance of the patient. It is only necessary to sit the patient upright behind a fluoroscopic screen and look for the diagnostic thin crescents of air beneath one or both leaves of the diaphragm. Perforating ulcers heal readily under medical treatment. It is not unusual to see a crater 1 cm. in diameter, disappear entirely in three weeks leaving only a small area of rigidity on the lesser curvature, which is gone in another two weeks.

Syphilis.—The roentgenological appearance of syphilis is that of carcinoma, except that mottling of the barium mass and stasis are uncommon in syphilis. The extent of the lesion is out of proportion to the patient's symptoms. The age of the patient, the history and the laboratory findings must be relied upon for corroborative evidence. Proper treatment will cause an improvement in the symptoms, but a defect in the outline usually persists and may be seen years after a clinical cure of the disease.

Linitis Plastica.—Linitis plastica (leather-bottle stomach) is a fairly rare condition, and is usually due to a low grade of malignancy. The gastric wall is infiltrated by dense, fibrous tissue, which causes the stomach to contract to a small, rigid tube lying high up under the liver, through which the meal pours in a few minutes.

Lymphoblastoma.—Lymphoma of the gastro-intestinal tract may be a primary lesion or part of a generalized process. The demonstration of multiple lesions in the gastro-intestinal tract is not unusual. In the stomach it presents an appearance easily confused with carcinoma or polypi. The lesions will disappear under carefully given roentgen treatment but the diagnosis is usually dependent upon the demonstration of the disease elsewhere in the body. The earliest lesions, simple mucosal invasions show as an increase in the size of the rugæ. The more extensive mucosal and submucosal tumors produce a rigid-appearing wall, or, if large enough, a filling defect. This defect is annular, diffuse, rugose, or polypose, according to the type of the process, in these respects closely resembling carcinomata and polyposis. A considerable deformity of gastric contour may not interfere with the passage of the peristaltic wave.

Foreign Bodies.—Hair-balls, masses of vegetable fibers and metallic articles are occasionally seen in the stomach. Their location may be confirmed by: (1) changing the position of the patient; (2) inflating the stomach with air; and (3) making a routine gastro-intestinal examination.

Hair or fiber balls present a characteristic appearance. The barium mixture adheres to them, thus outlining their structure, and they are visible for some time after the meal has left the stomach.

Polypi.—Polypi of the gastric wall are comparatively rare. When demonstrable, they appear as smooth, rounded holes in the barium shadow, which remain constant upon change in the position of the patient. There is no interference with peristaltic movement. They may become impacted in the pylorus and cause marked obstruction, thus simulating a carcinoma.

Polypi must be differentiated from foreign materials in the stom-

ach, such as food-masses, and from extragastric tumors. Their constancy, is the best diagnostic evidence.

There is a rare form of polypoid in which an area of the gastric wall is occupied by a broad mass of hypertrophic tissue, which causes a ragged defect, usually along the greater curvature in the middle third.



FIG. 210 — Polypoid of the stomach.

Diverticula.—True diverticula are rare. They are usually seen at the cardiac end, may be a centimeter or more in diameter and often contain residues after the stomach is empty. They cause mild atypical symptoms, or none at all.

Diaphragmatic Hernia.—In children, due to congenital defects in the diaphragm, various parts of the stomach and intestinal tract may be found in either side of the chest. In adults a portion of the

stomach may protrude through the left diaphragm as the result of trauma, which has caused tears in the muscle or separation of its attachment from the chest wall. Bullet or stab wounds may produce an opening in the dome through which the stomach or intestine may be forced. In older individuals it is not uncommon to find varying degrees of herniation of the cardiac end of the stomach through the esophageal opening. A localized backward curvature of the lower few inches of the esophagus should lead to the suspicion



FIG. 211.—Hernia of cardiac end of stomach through the diaphragm. Note the characteristic course of the lower esophagus.

of herniation. Careful examination in the supine and prone positions will determine the diagnosis. These patients often give a history suggesting chronic ulcer and they may have an anemia from chronic slight bleeding.

Postoperative Stomach.—The stomach after gastro-enterostomy is generally smaller and higher than the normal stomach. It empties rapidly, as a rule, although the emptying-time depends somewhat upon the size and position of the stoma. There is little peristalsis

visible. When present, it usually passes over the entire lower part of the stomach to the pylorus, where it forces some of the barium mixture through, unless the pylorus has been closed by either operation or disease. The stoma is best seen when only a small amount of viscous barium mixture has been administered and carefully massaged through the stomach into the jejunum. It may be necessary to turn the patient obliquely for the best view of the stoma.

Ulceration in the region of the stoma may be difficult to demonstrate. If an ulcer crater can be outlined and recorded on spot films the diagnosis is certain but in some cases this is not possible and the condition must be inferred from indirect evidence and the history, a localized area of tenderness, increased peristalsis and stasis in the stomach.

Fistulae involving the stomach, jejunum and colon are best demonstrated by an enema. Barium runs back into the stomach from a distended colon much more readily than it goes in the opposite direction.

Hypertrophic Pyloric Stenosis may occur in adults as well as in children. In infants there is gastric stasis. A residue beyond four hours in the absence of other pathology is the usual finding. The pylorus and duodenum are not well seen in infants, so no defects are to be expected. In adults, however, in addition to a residue beyond six hours, we find a pyloric ring two or three times the normal thickness, and usually an indentation on the base of the duodenal cap.

THE DUODENUM.

The normal first portion of the duodenum presents a smooth, rounded, triangular shadow, which is connected with the stomach shadow by a thin line of barium mixture in the pyloric canal when the sphincter is open. Its relation to the stomach, gall-bladder and liver varies with the type and the position of the patient, and with the size and shape of the stomach and liver.

The duodenum has a peristalsis of its own, and its filling and emptying are controlled both by the pyloric sphincter and the constrictive action of the junction of the first and second portions.

The rapidity with which the first portion of the duodenum fills depends upon the tone of the pylorus. This is influenced by the type of food in the stomach, the amount of food in the ileum and the general nervous tone of the patient. Reflex disturbances from gall-bladder, kidney, appendix or other abdominal viscera may cause marked pyloro-spasm. In hunger, achylia, gastric malignancy or gall-bladder disease, the entire duodenum may fill rapidly.

If there is delay in filling the first portion of the duodenum during the routine examination, the administration of a mint wafer or a conversation about the patient's favorite foods will usually cause relaxation of the pylorus.



FIG. 212.—Normal pylorus and duodenum.



FIG. 213.—Free gas between the upper surface of the liver and the diaphragm, following perforation of a duodenal ulcer.

The duodenum may be considerably enlarged in atonic individuals. Enlargement may also occur as a result of adhesions or bands about the duodenum, and ulcer of the second portion. It may be contracted as a result of spasm, scar tissue in the wall, or adhesions. Defects in the outline of the duodenum may be due to pressure, as, for example, the smooth, rounded depression caused by the gall-bladder, and the small indentation on the inner margin caused by the bile duct. Scars and the spasm from ulcers cause irregular deformities, which produce the familiar coral-shaped shadow. Rarely, as the result of perforation of a duodenal ulcer, there may be a pocket filled with barium either between the duodenum and the liver, or between the duodenum and the colon. In some cases of perforation free gas may be demonstrated in the peritoneal cavity above the liver. Adhesions generally produce slight irregularities. Spasm may produce extensive changes in the shape of the duodenal bulb.

Ulcer.—The signs of ulcer are: (1) deformities in the outline of the duodenal bulb; (2) the presence of a small fleck of barium in the crater; (3) changes in the mucosal pattern; (4) changes in motility; (5) changes in gastric peristalsis.

The deformity of outline must be differentiated from that produced by spasm of extrinsic origin. The deformity of ulcer is constant, whereas that due to spasm will vary, or disappear entirely, upon different examinations. It is probable that a part of the deformity observed in duodenal ulcer is due to the local spasm accompanying the lesion. The most definite evidence of ulcer is the demonstration of a niche. The presence of a small, round mass of barium 1 or 2 mm. in diameter projecting from an area of infiltration on the margin, or showing through the general outline with pressure, is diagnostic.

There is a tendency for the mucosal pattern to assume a stellate appearance and the puckering of the folds may indicate the location of the crater. If no fleck is found in such a case it is usually safe to assume that the ulcer is healed. In cases where palpation is dangerous or difficult, ulcers about the pylorus may be well visualized with the patient supine and the right side elevated, so that air in the stomach will occupy the region of the antrum and the duodenal bulb. This will permit the demonstration of the mucosal pattern in this area without the necessity of manipulation.

Increased gastric peristalsis is an almost invariable accompaniment of duodenal ulcer. The emptying-time of the stomach will

depend upon the size and position of the lesion, and the amount of obstruction caused by it. When the ulcer is small and well above the pyloric ring, the emptying-time may be shortened. Large ulcers, or ulcers involving the pyloric ring, are generally accompanied by gastric stasis.

Adhesions may produce slight irregularities in the cap which are not constant with change in position of the patient. Constriction bands may be found anywhere in the course of the duodenum. They may cause a dilatation and a delay in motility with pendulum-like movements of masses of barium in the second and third portions



FIG. 214 — Duodenal ulcer with crater

Thin, atonic individuals, more often women, with a low mesentery and stomach, may show delay and dilatation in the second portion of the duodenum, due to pressure from the root of the mesentery across the third portion, which disappears when the patient lies face down. Nausea is usually associated with dilatation and delay in the second portion of the duodenum.



FIG. 215 — Duodenal ulcer of the type simulated by spasm.

Diverticula of the duodenum are seen occasionally. They appear as rounded masses in close proximity to the duodenum. They may measure several centimeters in diameter and contain barium residues long after the adjacent intestine is empty. The presence of mucosal folds within the diverticula signifies that they are of congenital origin.

Fistulae between the duodenum and the gall-bladder have been demonstrated, and in rare cases the barium meal may outline an enlarged common duct.

Carcinoma of the duodenum occurs by extension from the surrounding organs, most commonly the bile ducts. It rarely arises from the intestinal mucosa. In either case the roentgen appearance is the same. There are annular or irregular defects. Cavities may develop within them which communicate with the lumen and give shadows resembling diverticula.

THE JEJUNUM AND ILEUM.

The jejunum normally appears as coils of fine, feathery flakes, due to the rapidity of the passage of the meal through it. It is never well filled except in pathological conditions, the most common of which are peritonitis (acute or chronic) and obstruction.

A tumor sufficient to cause obstruction is, as a rule, palpable. In peritonitis and obstruction, the flocculent appearance disappears, and the coils are dilated. Gastro-jejunal ulcer may occur following a gastro-enterostomy. The diagnosis is based upon: (1) a persistent irregularity of outline (often difficult to visualize) in the region of the stoma; (2) a localized tenderness over the stoma; (3) a change in gastric peristalsis; (4) a gastric residue beyond the six-hour period; and (5) demonstration of a fleck at the site of the ulcer. This fleck is often best demonstrated by palpation under the fluoroscopic screen after the administration of a small barium meal. The ulcer is often located some distance below the stoma and, unless carefully looked for, is easily missed.

Steatorrhea.—In a few cases showing deficient fat digestion and general rarefaction of the bones, a striking change has been seen in the duodenum and jejunum. The intestine loses its fringed margin and the barium collects in large, smooth lumps, suggesting colon masses. Anemia, skin lesions and an atony of the colon may be associated with the process.

Sprue.—Sprue is a somewhat similar condition usually seen in individuals who have spent some time in the tropics. The jejunum loses its sharp feathery outline, because of edema of the mucous membrane. There is a general irritability of the small intestine and the barium tends to collect in isolated masses in adjoining loops of the intestine. There is no change in the rate of passage of the meal. Severe cases may be mistaken for regional ileitis.

The normal ileum appears as a coil of intestine containing dense masses of barium lying low in the pelvis, with a loop extending upward and terminating in the cecum. Owing to its depth in the pelvis, palpation is unsatisfactory except in its terminal portion. It is smooth in outline, with constantly changing transverse con-

outline and either dilatation or contraction of the affected portion, with delay in the passage of the meal through it.

Fistula into the ascending colon or sigmoid may occur.

Tenia may cause marked irritability of the ileum and in a few cases the diagnosis of an ascaris infection has been made from defects in the barium shadow made by the worms or from an opaque residue in the parasites after the intestine has emptied.



FIG. 218.—Regional ileitis. Congenitally high position of the cecum. Ileo-cecal valve indicated by the arrow. The cecum is also involved in the process.

Multiple diverticula have been demonstrated on the jejunum and ileum. As is the case with diverticula elsewhere, they are often best recognized by the residue remaining in them after the intestine is empty. Meckel's diverticulum is a small pouch 2 or 3 feet above the ileocecal valve, which is of significance as a possible cause of obstruction or unexplained bleeding but is very rarely demonstrated.

THE APPENDIX.

The normal appendix is generally visible at some time during a gastro-intestinal examination, and it may be seen to fill and empty. It should not remain filled after the cecum has emptied. It is freely movable and not tender. It may present one or more constrictions which are without significance.

The evidence of acute disease of the appendix is: (1) marked local tenderness; (2) absent or incomplete filling; (3) delay in the ileum; (4) spasm of the pylorus and duodenum.

In the subacute stage it may fill irregularly and contain a residue after the cecum is empty, or it may remain unfilled. There is usually moderate local tenderness and reflex disturbance of the pylorus is less apt to be present. If an abscess has formed about it, there will be a varying amount of deformity in the cecum and a mass may be felt corresponding to the defect. In the so-called "chronic appendix," where infection has come and gone, there may be no evidence of the process other than fixation and a failure to empty. An appendix which retains barium several days after the ascending colon has emptied is a potential source of trouble. Stones or other foreign bodies may occur in the appendix and be mistaken for ureteral calculi.

THE CECUM.

The normal cecum is smooth, with transverse constrictions. It is freely movable both vertically and laterally, and it varies greatly in size, position and mobility. In order to identify it, a filled terminal ileum is often necessary. The cecum may be dilated in cases of obstruction in the distal colon, and in spastic constipation. In cases of extensive adhesions, and congenital anomalies, it may be contracted.

Changes in outline (demonstrated best by enema) may be due to adhesions, fecal masses, carcinoma, inflammatory changes or intussusception. A diseased appendix with abscess formation may produce a filling defect resembling that of carcinoma. However, a careful observation will generally show the process to be outside the cecum.

Carcinomata and other malignant tumors of the cecum generally show an annular, mottled, irregular filling defect, which is constant upon repeated examinations. It is easily overlooked unless the examination is made with an opaque enema. The defect may be slight, or it may obstruct the cecum to such an extent that

very little of the barium mixture can be injected. In this type there is, as a rule, considerable dilatation and stasis in the terminal ileum. The observation made twenty-four hours after the administration of the barium meal may be of more value than one following a barium enema.

The ulcerative type of tuberculosis of the cecum produces local irritation, so that the barium meal or enema does not remain at the site of the lesion. A typical finding is stasis in the ileum and an empty ascending colon at twenty-four hours. An enema reveals either defects in outline, or failure to fill at the site of the lesion. The normal mucosal pattern is lost. When the lesion is of the indurative type the appearance resembles that seen in carcinoma, but unlike carcinoma the process usually extends into the terminal ileum.



FIG. 219.—Intussusception. Invagination of the ileum into the ascending colon. The loop of ileum extended beyond the hepatic flexure. The arrow indicates spiral lines of barium about the invaginated ileum which are diagnostic of the condition. The lack of barium at *B* is due to gas in the colon. The transverse colon is marked *A*.

Intussusception produces a characteristic appearance when a barium enema is given. The ileum, on being injected,

lie within the ascending colon or extend into the descending portion. The distal end is rounded, producing a cup-shaped depression in the shadow of the opaque material in the colon. Multiple fine streaks of barium encircle the dilated ileum. With careful manipulation under fluoroscopic control, some of these invaginations may be reduced.

The normal cecum is never empty when barium is present in both the ileum and the ascending colon. Any colon sufficiently filled by enema will overflow into the terminal ileum.

THE COLON.

The colon varies in size and in position from hour to hour, and it also varies in different individuals. The outline is smooth and shows the usual haustral segmentations. Normally, the meal reaches the splenic flexure within twelve to eighteen hours, and the colon is entirely empty within twenty-four to seventy-two hours.

The movements of the colon are: (1) haustral churning, *i. e.*, formation and reformation of haustral contractions; (2) antiperistalsis, which begins as a contraction ring at about one-third of the distance between the hepatic and splenic flexures and runs slowly backward to the cecum; (3) pendulum-like movements of large masses which move to and fro through short distances; and (4) rapid mass movement through a considerable portion of the colon with disappearance of haustral markings.

In outlining the colon by enema, it takes a few minutes to complete the filling of the rectum and sigmoid, after which the fluid passes readily to the cecum. As the pelvic loop of the sigmoid distends, it should rise well out of the pelvis. If it fails to rise, adhesions should be suspected.

Anatomical Variations.—There is wide variation in the size, shape and position of the colon, and of its various portions. There may be a complete transposition of the viscera; the ascending colon may be incompletely developed; the cecum may lie high in the region of the gall-bladder; and the hepatic flexure may be seen in front of and even above the liver.

The sigmoid, in addition to extreme variations in length, may have either a short or a relatively long mesentery; and, for this reason, its position in the abdomen is subject to wide variation.

Changes in Size.—The colon may be dilated as a result of malformations, obstruction from congenital bands or tumors or an overactive sympathetic nervous system. The lumen of the transverse and descending portions is uniformly diminished in spastic constipation. In general it may be said that the length and size of the colon is an index of the balance between the vagus and sympathetic systems. When the former prevails, the colon is short and narrow. A preponderance of the sympathetic element produces a redundant, atonic colon.

Changes in Position.—Changes in position are not important unless they cause obstruction. A long sigmoid loop may lie almost anywhere in the abdomen, or the transverse colon may be found low in the pelvis without the patient suffering any ill effects. In the normal individual, in the upright position the flexures do not ordinarily drop below the iliac crests.

Changes in Outline.—In the observations following a barium meal, the colon often presents irregular defects due to the presence of fecal matter. If disease of the colon is suspected, an examination by means of an opaque enema should be made. The most common defects noted in the colon are the annular, ragged, funnel-shaped deformities due to carcinoma, and the constrictions caused by bands of adhesions. Multiple, small bud-like masses are sometimes seen along the margins of the colon, particularly in its descending portion. They represent barium-filled diverticula, and a certain amount of irritability and segmentation usually accompanies them. It has been noted that there is a complete absence of segmentation in severe cases of colitis. Where irritative lesions are present in and about the colon the haustral markings are apt to be fine, irregular in depth and close together. General spasm is evidenced by a narrow colon, particularly in the descending portion, with broad and widely-spaced segmental markings.

Changes in Motility.—Decreased emptying-time occurs in achylia, in conditions which produce a rigid incompetent pylorus and in colitis. Increased emptying-time, or constipation, appears in three forms: spastic, atonic, and rectal.

1. The spastic type is the result of increased vagal tone. It involves mainly the transverse and descending colon and is shown by a diminution in the size of the lumen, and changes in haustral segmentations which become fewer in number and increased in width. The delay in these cases may be extreme, barium remaining in the colon as long as a week after the meal.

2. The atonic type is characterized by a large, redundant flabby colon. It is less common than the spastic variety. The most severe forms are seen in asthenic states where there is a general loss of tone.

There is, of course, more or less delay in cases of obstruction due to adhesions or tumors. In acute intestinal obstruction, films of the abdomen should be obtained before the administration of barium. These films will often reveal coils of gas-dilated intestine, which, by their character and position, determine the site of the lesion. If the small intestine is affected, the coils lie mainly transversely and occupy the left three-fourths of the abdomen. Their margins present the fine markings characteristic of the small intestine. If the colon is involved, the coils are larger, and smoother with few haustral segmentations and they lie on both sides of the abdomen. If the obstruction is low in the colon marked distention of the cecum is to be expected. The dilatation generally ends abruptly at the point of obstruction.

Carcinoma.—The early diagnosis of carcinoma of the colon is difficult. Unless the examination is made by enema, as well as by the barium meal, the lesion may be overlooked.

Care should be taken in the preparation of the patient for the examination by enema. The large bowel should be cleansed of fecal matter. This is best accomplished by a cleansing enema of normal salt solution. Irritating substances must not be used. This cleansing enema should be given two or three hours before beginning the barium examination, and an effort made to have it well evacuated. If there is any question of obstruction, the examination by enema should precede barium by mouth. In these cases, the administration of barium by mouth might produce a complete obstruction.

The amount of the opaque enema should be sufficiently large to fill the entire bowel—about 1 to 2 quarts. The mixture should be warmed to body temperature. It should contain a sufficient amount of barium to produce a shadow of good contrast, but not enough to interfere with its free passage through the rectal tube. A mixture of barium water and petrolagar of about the consistency of thin cream is quite satisfactory.

The gravity method of administering the opaque enema is the most satisfactory. The examination should begin with the patient face down upon the fluoroscopic table, and the entire filling should be observed carefully, turning the patient from side to side during the progress of the enema to separate loops and bring as much of the wall into profile as possible. Films should be obtained

either during the examination or after the filling is complete, whichever the fluoroscopic findings suggest. The fluoroscopic examination is essential, for the films alone may be misleading. The bowel may be emptied by lowering the container and permitting the mixture to flow back into it. In this way the manner in which the colon empties may be observed on the fluoroscope or the patient is



FIG. 220 —Carcinoma of the transverse colon at A. On the opposite side, there is a narrowing of the gut, due to spasm.

allowed to evacuate the enema, after which the patient is fluoroscoped and films made.

For the demonstration of polyps and small lesions, it is often helpful to fill the colon with air after the barium has been evacuated.

Normally, the colon dilates considerably during the first part of the injection. There is a delay in the lower sigmoid, at the splenic

and hepatic flexures, and wherever sharp angulation occurs. Delay may also be due to the presence of: (1) gas; (2) fecal matter, or (3) obstruction to the free flow of the mixture from the container.

When organic obstruction (either benign or malignant) is present, the portion of the gut below the obstruction dilates to an abnormal size. This is particularly true of the rectum. There is a definite delay in the passage of the enema beyond the lesion. Unusual spasm may be observed in the filled portion, and the patient complains of pain and difficulty in retaining the enema.

Carcinoma of the colon differs from other forms of obstruction in the character of the shadow cast by the obstructed area; also by the amount of pain and the difficulty in retaining the enema, which are out of proportion to the amount of obstruction. The shadow of the involved area may be 2 or 3 inches in length. The defect is irregular in outline, usually annular, and the relief pattern of the mucosa is replaced by an irregular mottled appearance characteristic of carcinoma elsewhere in the intestinal tract. Strictures of inflammatory origin are more sharply defined, and do not present mottling. Spasm of the colon may simulate carcinoma, but in spasm the deformity is not constant and there is little, if any, obstruction to the passage of the enema. When the lesion is in the cecum, the enema may pass directly into the ileum without filling the cecum. In this case the barium mixture in the area of the cecum appears as a ragged, mottled shadow.

Carcinomata of the colon which do not invade the lumen may be overlooked unless an examination is made after evacuation when defects in the mucosal pattern may be evident. Multiple lesions are rarely due to carcinoma.

Diverticula of the Colon.—This condition is more common than is generally supposed, and is probably frequently overlooked in the routine gastro-intestinal examinations. The diverticula are generally best demonstrated by repeated examinations following the oral administration of barium, although in some cases the picture after the injection of a barium enema is more characteristic.

Diverticula appear as bud-like masses projecting from the lumen of the colon. They may appear in any part of the bowel, but are more commonly seen in the distal portion. They frequently retain the barium mixture for days or weeks. When the colon is filled with the barium mass, they may be completely obscured by its shadow. For this reason, in cases where diverticula are suspected, the colon should be observed after it has had sufficient

time to empty (up to twenty-four or forty-eight hours). The residue remaining in the diverticula may then appear as small, dense masses scattered along the course of the colon.

Chronic ulcerative colitis produces a rigid tube-like transverse and descending colon with no sign of haustration. This must not



FIG. 221.—Diverticula of the colon demonstrated by a barium enema. Note the bud-like projections as indicated by the arrows.

be confused with the absence of haustral markings observed immediately after filling by enema. It often takes a few minutes for the normal colon to develop constrictions. It should be kept in mind that in some cases of ulcerative colitis islands of regenerating mucosa may give a mottled appearance to the barium shadow suggesting a diffuse polyposis. The defects in the barium shadow are small—

usually 2 to 3 mm. in diameter, and the colon is narrow and rigid. (Fig. 222.)

Polyps may be found in any part of the colon but are common in the descending colon or sigmoid. They appear as rounded transparent areas in the barium or as lobulated cauliflower-like impressions. They are best demonstrated by inflating the colon with air after a tenacious barium enema has been evacuated.



FIG. 222.—Ulcerative colitis.

A diffuse polyposis of the colon is sometimes seen in early life. The barium shadow is coarsely mottled throughout the greater portion of the colon, producing a characteristic picture. The condition is associated with recurring attacks of diarrhea and hemorrhage.

It should be remembered that multiple defects in the colon are rarely due to carcinoma. They may be caused by lymphoma, polyps, anæmic granulomata or peridiverticular inflammation.

Volvulus.—A long sigmoid may rotate upon its mesentery sufficiently to cause a complete obstruction of a localized loop which becomes greatly dilated. It usually occupies the lower central portion of the abdomen.

THE RECTUM.

The rectum appears as a smooth S-shaped shadow occupying a considerable portion of the pelvis. Defects in outline, when due to carcinoma, present the ragged, annular deformity characteristic of the disease. Ulceration due to lues, granuloma inguinale or tuberculosis may produce more or less infiltration of the wall, in which case the wall becomes rigid, and the diameter of the intestine is diminished rather uniformly throughout the area of the lesion. Pressure from inflammatory masses or tumor in the pelvis may either deform or displace the rectal shadow.

THE LIVER.

The liver is seen as a triangular, mass filling the right upper quadrant. Normally it is of a homogeneous density, except when obscured by intestinal shadows. The hepatic flexure in some instances appears to lie upon the upper surface of the liver and may be partially filled with gas. Gas bubbles within the substance of the liver, with fluid levels below them, occur in abscesses due to a gas-forming organism. If gas bubbles are not present, the only evidence of abscess is an increase in size.

Echinococcus disease may cause great enlargement of one or more lobes of the liver. Occasionally a cyst will show thinly calcified walls. The liver is also increased in size in cirrhosis and in metastatic malignant disease. It is reduced in size in cirrhosis and acute yellow atrophy.

THE SPLEEN.

The spleen is fairly well seen when surrounded by the gas-filled stomach and intestine. In cases where its outline is not clear, inflation of the stomach and colon with air will demonstrate its size and shape. Enlargements are usually quite evident and they carry the splenic flexure of the colon downward and inward. Small calcified spots scattered through the substance of the spleen are occasionally seen. These are due to healed foci of tuberculosis or to calcified thrombi.

The liver, spleen and the reticulo-endothelial system may be

well outlined by the intravenous injection of colloidal thorium, but this procedure carries the possibility of a future aplastic anemia, due to the radio-activity of the thorium.

THE GALL-BLADDER.

Gall-stones may be visualized if they contain a sufficient amount of calcium salts, which, unfortunately, is true in only a small percentage of the cases. They appear as single or multiple shadows, which may be either the typical faint ring, a dense homogeneous mass, or a mottled area of density due to many small stones packed together.

Gall-bladder diagnosis has been revolutionized by the Graham method of visualization. The iodized dye is given intravenously as recommended by the originator, or intra-orally in capsules or emulsion. The results seem equally satisfactory with both methods. The important point with either is to make sure that the patient takes no food after the dye is given until the first films have been made. The gall-bladder is visible five or six hours after the dye is administered and becomes increasingly dense up to fifteen to eighteen hours. A common technic is to give the dye orally after dinner and take films the following morning at nine and eleven, the patient receiving no breakfast. He is then instructed to eat a lunch with considerable fat, and a third set of films is made at 1 P.M. In this way two observations of the filled gall-bladder and one partially emptied are available, giving sufficient information upon which to base an opinion. Single films following the dye are not enough. If the gall-bladder is not visualized, a second dose of dye is given the following night and further films secured the next day. If no shadow is obtained after two such examinations, one may be reasonably sure that the gall-bladder is diseased, the cystic duct occluded, or the liver seriously damaged.

By employing an i-omer of tetraiodo-phenolphthalein intravenously and testing the blood colorimetrically the liver function may be estimated at the same time. The fact that a gall-bladder shadow is obtained does not exclude the presence of cholecystitis. Between 10 and 20 per cent of well visualized gall-bladders may be infected, but usually the disease is not of sufficient degree to warrant operative interference.

The only contraindication to the use of the dye in an obstructive jaundice of high degree.



FIG. 223.—This plate shows a fairly typical group of gall-stone shadows



FIG. 224 —Normal gall-bladder made visible by the ingestion of tetraiodophenolphthalein.



FIG. 225.—Roentgenogram showing a single gall-stone



FIG. 226.—Non-opaque gall-stones made visible by the injection of tetrastannous iodine

The normal gall-bladder is fairly well seen at fifteen hours. It may be located anywhere from the costal margin to the top of the sacrum. It may overlies the lumbar spine or be concealed by dye contained in the ascending colon. Repeated films from various angles may be necessary at this first visit. At seventeen hours the shadow is somewhat better defined and of about the same size. After food it should contract to about one-half its previous size or disappear entirely. Gall-bladder function is closely related to that of the stomach or duodenum. When there is delay in the emptying time of the stomach, gall-bladder emptying may be similarly slowed or absent.

One occasionally sees a gall-bladder with the tip curled up and a constriction across the junction between the tip and the body. This appearance is not due to the presence of adhesions but to a fold of mucous membrane within the gall-bladder. It is probably a developmental anomaly. Haziness of the fundus may be present after cholecystotomy.

The pathological gall-bladder usually fills faintly or not at all. It may be fairly well visualized and fail to contract after food. Some cases fill and empty in a perfectly normal manner. However, the majority of these are not sufficiently pathological to require surgery.

If a gall-bladder fails to fill, it is wise to repeat the observation before radical treatment is undertaken.

Small benign tumors within the gall-bladder may be mistaken for stones. They are best seen on the films taken after the fat meal. Papillomata produce small rounded defects in the shadow less than 5 mm. in diameter usually found along the lateral wall. When multiple they are well separated and never grouped together. Adenomata are larger (8 mm. or more in diameter) and they occur at the fundus. Defects due to these growths are unchanged in position throughout the examination. In a few cases films of the patient upright have shown a layer of small light stones floating on a level of heavy dye beneath them.

Cysts.—Cysts in the abdominal cavity may be urogenital, lymphatic or hydatid. The first group occurs in or about the kidneys, behind the colon or in the pelvis, lymphatic cysts are usually found near the root of the mesentery and hydatids may be seen anywhere, more commonly in or near the liver.

Pneumoperitoneum.—Inflation of the peritoneal cavity with air or gas is a spectacular way of demonstrating the abdominal

viscera and, in selected cases, this method has a definite place in roentgenology. The liver, spleen, kidneys and frequently the pelvic viscera are brought out with startling clarity. It is particularly useful for the demonstration of adhesions to the abdominal wall, the relation of tumor masses to the abdominal viscera and the visualization of the subdiaphragmatic space.

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CHAPTER X.

THE GENITO-URINARY TRACT.

Preparation of the Patient.—The preliminary preparation of the patient is a matter of opinion. If it is thought advisable, a vegetable cathartic or oil may be recommended. Mineral salts and enemata should always be avoided, the former because they tend to fill the intestine with fluid, the latter because air generally accompanies their introduction, and they are seldom entirely expelled. Fluid or air in the intestine may entirely obscure the kidneys and produce a confusing shadow. Good films are usually obtained with no preparation.

Technic.—The examination should include both kidneys, the courses of the ureters and the bladder. Doubtful shadows and most positive findings should be checked with a second examination at a later date. This work requires films of the best technical quality. Roentgenograms which show evidence of motion, due to respiration or other causes, should be rejected. Films of the bladder area should be obtained in both anteroposterior and postero-anterior positions. The ideal kidney film should be of moderate density, thin rather than overexposed, and should show clearly the last two ribs, the transverse processes of the vertebræ and the margins of the *psoas muscles*.

THE KIDNEYS.

The normal kidney shadow is of the familiar form: in length approximately equal to three vertebral bodies—the twelfth thoracic and first and second lumbar—and of smooth, regular contour. *The right kidney lies 1 to 2 cm. lower than the left, and is seen less frequently.* Visibility depends upon the amount of fat about the organ, and the accuracy of the technic.

The kidneys are somewhat movable in the normal individual, dropping 1 to 3 cm. in the change from the supine to the standing position. In young children they are lower than in adults. They lie close to the margin of the *psoas muscle*, and are crossed by the shadows of the last two ribs.

Changes in size of the kidneys are not diagnostic. The shadow may be distorted or enlarged by the size of the patient and the position of the tube, or one of the kidneys may be hypertrophied as a result of disease in its fellow. On the other hand, the shadow may be of normal size although the kidney may be damaged. Very small, slightly lobulated, kidneys are sometimes seen in chronic nephritis.

Changes in shape are due to tumors, cysts, infections, anatomical variations and abnormal position.



FIG. 227.—Large branching calculi in both kidneys.

Changes in position may be temporary or constant. The kidney may rotate on any one of its axes, or it may be displaced downward, away from or toward the median line. It is rarely, if ever, displaced upward. One or both kidneys may be affected. Downward displacement is the most common and occurs in ptosis, in tumor arising from the upper pole of the kidney, and occasionally in other retroperitoneal tumors. An abscess behind the psoas muscle, or a tumor arising in this region, may displace the kidney away from the spine. In congenital malposition of the kidneys, they may be found in the pelvis or overlying the vertebræ.

Changes in density are extremely unreliable in diagnosis. While it is true in rare cases that tuberculosis of the kidney may be sus-

pected because of the presence of a mottled shadow of increased density, in general mottling is due to overlying intestinal shadows.

The principal value of the plain roentgen-ray examination lies in the detection of calculi. Under the most favorable conditions, 80 per cent of all kidney and ureteral (not bladder) stones will show. Their visibility depends upon: (1) the technic; (2) the preparation



FIG. 228 —Roentgenogram showing multiple calculi in the kidney.

and size of patient; and (3) the composition and size of the stone. The first two factors may be controlled to some extent by repeated examinations. In regard to the third factor—the composition and size of the stone—the order of visibility is as follows: urates and xanthin invisible, cystine faintly visible under favorable conditions, calcium phosphate, carbonate and oxalate, always evident

on good films. Stones which lie in large, inflamed kidneys may be so obscured by the general density surround them that they are not visible. Furthermore, the shadow of a stone may overlie a rib, the transverse process of a vertebra or the sacrum, and may be overlooked. Sometimes a stone previously invisible will receive a coating of opaque mixture during pyelography and become visible. Stones generally occur in the region of the pelvis and lower calices. They may be round, although they are often irregular, and occasionally assume the form of a cast of the pelvis in which they are located.

A single shadow may represent multiple stones—a diagnostic point not to be overlooked. Discrete shadows scattered throughout the periphery of the kidney shadow suggest a marked degree of hydronephrosis with stones or an old tuberculosis of the kidney. With large, branching calculi, there is generally considerable kidney damage.

When multiple stone formation is encountered in the kidneys, parathyroid adenoma may be suspected, and the skeleton should be investigated for evidence of disturbance of calcium metabolism. In a few cases following fractures of the thoracic spine, multiple stones have formed in the kidneys within a few weeks after the injury.

Shadows which may be confused with calculi are:

1. Those due to material in the bowel, such as fecal masses, fruit pits, enteroliths, opaque salts, bismuth and barium (particularly residues in diverticula of the colon) Bland's pills and salol capsules.

2. The appendix often lies in close relation to the right ureter, and foreign bodies or enteroliths within it may be mistaken for ureteral calculi.

3. The shadows of gall-stones can generally be differentiated from those of renal calculi, (a) by their structure and (b) by their shifting position with reference to the kidney area, as shown in films obtained in the anteroposterior and postero-anterior and lateral positions.

4. Calcified glands produce a shadow of a characteristic spongy appearance, which is usually sufficient to identify them. They occur along the course of the mesentery and in the region of the sacro-iliac joints. They may be identified by their location which is, roughly, in a line extending from the left kidney downward across the abdomen to the right iliac fossa. They may also be identified by the fact that they frequently change position in relation to the other structures of the abdomen.

5. Tuberculous foci in the kidney may calcify and cast shadows which resemble those of renal calculi.

6. Calcification of tumor masses in the pancreas, or in the region of the kidney may be a rare cause of confusion.

7. The tip of the transverse process of a vertebra may be of such greater density than the body as to suggest a stone.

8. Small areas of density in the spleen may overlies the upper portion of the kidney.

9. Calcification in a blood-clot or surrounding a foreign body may simulate the appearance of a renal calculus.

10. Mention must also be made of the shadows cast by fibromata on the skin, scars, and even dressings, which may be recorded on the film as areas of increased density.

11. Artefacts in films, due to thin spots in the emulsion, or small areas which are unequally developed may be sources of confusion.

In searching for small stones in a kidney which has been operatively exposed, it is possible to take films directly through the mobilized kidney when it can be freed sufficiently from the surrounding tissues.

Retrograde Pyelography is not a procedure to be undertaken lightly. Reactions cannot be entirely avoided, although a careful technic will do much toward preventing them. The most important single precaution to be observed is to permit the solution to flow in slowly under a slight gravity pressure, and to stop as soon as the patient complains of pain in the kidney. The fluid level in the container from which the solution flows is a safe guide. As the pelvis becomes filled, this level becomes stationary.

The outline of the kidney pelvis as obtained by this method varies greatly. The normal pelvis is somewhat lily-shaped, with the ureter corresponding to the stem. The pelvis presents a more or less rounded border with which the ureter blends on its inner margin. Arising from the outer margin of the pelvis, there is a variable number of processes projecting into the kidney substance, the major calices, from the tips of which arise further small projections the minor calices. There is great variability in the shape and size of the kidney pelvis. One may see a small globular pelvis with short calices or a large extensively branched pelvis with the tips of the calices well out in the kidney substance.

Incomplete filling of the pelvis is generally the result of spasm of the ureter or pelvis, commonly caused by too rapid distention with the opaque medium. Pressure from enlarged, adjacent organs

and extrarenal tumors may also prevent complete filling. The film may show no solution in the kidney, a small, irregular, bazy shadow, or what appears to be a markedly deformed pelvis. Re-examination with a more gentle technic will, demonstrate whether one is dealing with spasm or an organic lesion.

The mobility of the kidney may be determined by an examination following pyelography in both the supine and the erect positions. This examination is also useful for the recognition of ureteral kinks.

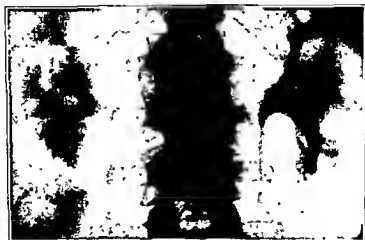


FIG. 229.—Injected kidney pelvis showing an anatomical variation.

Intravenous Pyelography permits visualization of the kidney pelvis, ureters and bladder. It is a simple procedure which can be done in any roentgen-ray laboratory, and furnishes in many cases all the information necessary in regard to the conditions present.

Contraindications are severe liver disease or iodine sensitivity on the part of the patient.

Films are made five, fifteen or thirty minutes after the intravenous injection and often an hour or more later according to the rate of excretion.

The visualization of the pelvis and ureters is often equal to that obtained by retrograde pyelography. A valuable part of this method of examination is the demonstration of kidney function. The functional capacity of each kidney can be estimated from the rate of excretion and the density of the pelvic shadows. Excretion may be

suppressed in the kidney above a ureteral stone or following trauma to a ureter or bladder. A stone which is not visible on the plain films may be suspected from the suppression of excretion in the kidney above it. (Fig. 230.)



FIG. 230.—Intravenous pyelogram showing no excretion from the left kidney due to the recent impaction of a triangular stone in the upper ureter.

Excretion may be delayed in both kidneys or there may be complete absence in one from a variety of causes such as tuberculosis, pyonephrosis or tumor formation. Such a finding should be checked by the retrograde method. Intravenous pyelography is ideal for children.

The method may fail to reveal the earliest evidence of tuberculosis or malignant disease, as the deformities they produce are not so obvious as with retrograde pyelography. The best visualization occurs where the kidney substance is actively secreting and in cases of chronic obstruction where the dye is prevented from leaving the kidney.

Anomalies, particularly the presence of multiple pelves and ureters are best demonstrated by this method as well as displacements or aberrant vessels and it helps to localize and identify questionable tumor masses in the upper abdomen.

Variations in development are relatively common in the genito-urinary tract. The kidney pelves may be small, infantile, branched or divided. The kidneys may be rotated, displaced, fused across



FIG. 231.—Hydronephrosis, demonstrated by injection with opaque solution.

the spine or one may be absent. A double pelvis will have double ureters which may fuse at any point in their course or continue into the bladder as separate structures. A double pelvis should always be suspected when retrograde pyelography shows only a small pelvis located toward either end of a kidney shadow. They are less apt to be overlooked after intravenous pyelography.

Horse-shoe kidney occurs from a partial or complete fusion of the

kidneys across the spine. The lower poles of the pelves and the ureters are displaced toward each other and occasionally an extra pelvis may be present in the central portion.

Hydronephrosis.—Hydronephrosis produces every degree of change, from blunting of the minor calices to the formation of a large sac. These changes depend upon the site of the obstruction and the length of its duration. With obstruction near the kidney, the characteristic early change is blunting of the minor calices.

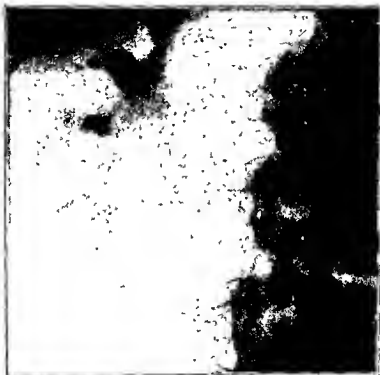


FIG. 232.—Infection of the lower calix of the kidney suggesting tuberculosis.

With obstruction near the bladder, on the other hand, dilatation of the pelvis and a certain amount of rounding of its outline are the characteristic findings. In the later stages of the process, both major and minor calices may disappear. The opaque solution collects in one large pool in the sac which is all that remains of the kidney. At times this sac may have several pockets, each one of which collects a pool of the solution. This condition may not be obvious in the routine supine position, but with the patient erect, each pocket presents a fluid level.

A moderate degree of hydronephrosis is often seen during the course of pregnancy. It disappears soon after delivery.

The films may also give an indication of the cause of the condition, such as stone in the ureter, kinks or dilatations. It is possible to estimate roughly the amount of kidney damage from the amount of solution the pelvis will hold. Anything under 20 cc. may be considered normal.

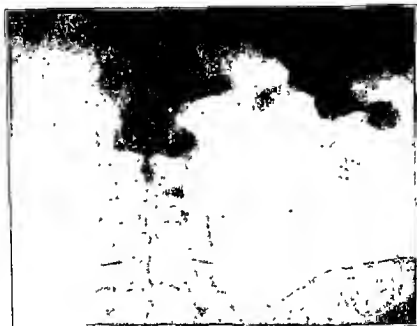


FIG 233.—Pyonephrosis. The kidney pelvis is extensively infected.

Pyonephrosis.—In inflammatory conditions, the principal change is in the calices. They are likely to show irregular, moth-eaten edges, and an increase in length and width. In the later stages, they may show rounded dilatations at their extremities. The form of the pelvis varies according to both the amount of destruction of the kidney substance and the degree of distention of the pelvis. Ordinarily, the pelvis is contracted rather than dilated.

Tuberculosis.—Tuberculosis begins as small abscesses in the kidney substance which may remain discrete or unite and connect with the pelvis. The roentgen findings depend upon the stage of the process. Plain films in long-standing cases may show a finely dotted or rose-

petal calcification in the kidney substance. Pyelography in early cases will show nothing or perhaps a slight irregularity of one calix or a small abscess cavity connecting with it. As the process advances, more deformity occurs in the pelvis until in the late stages it takes the form of an irregular mass surrounded by multiple abscesses. The ureter is involved in the more advanced cases. An early sign is a stiffening of the lower portion and a straightening out of the curve above the bladder, so that the affected side moves near the mid-line. Later the ureter becomes tortuous, irregular in outline, and may show strictures.



FIG. 234.—Tuberculosis of the kidney. Note the irregular areas of calcification scattered through the kidney substance.

Tumors.—The benign tumors of the kidney are cysts and adenomata. The latter may occur anywhere in the kidney substance or nose within the pelvis.

The malignant lesions are: (1) adenocarcinoma of the kidney substance; (2) papillary epithelioma of the pelvis; (3) hyper-

nephroma (from a true adrenal rest); (4) embryonal or teratoid tumors of various types. Perhaps the most interesting of these is the Wilm's tumor, an embryonal mixed tumor, usually a myxosarcoma.



FIG. 235.—Early adenocarcinoma 1 cm. in diameter involving the lower calix.

In addition to these, the kidney may be deformed by or involved in adrenal tumors of various types, such as (1) adenoma, carcinoma or neurocytoma; (2) retroperitoneal lymphoma; (3) teratoma. The deformity produced by a tumor depends upon the size and location of the growth. The characteristic picture is an obliteration of a portion of the pelvis with its corresponding calices. The kidney shadow may show a localized enlargement or a lobulated appearance. Tumors or cysts in the kidney substance may be overlooked until they reach a size sufficient to deform one or more calices. In the early stages, carcinomata usually manifest themselves by a deform-

ity of a single calix. When a large part of the kidney is involved, the pelvis may be reduced to a small mass from which strands of opaque material extend outward into an enlarged kidney area. This latter type of growth must not be confused with polycystic kidney.

The epitheliomas of the pelvis are usually warty outgrowths arising from the pelvic mucosa and they produce a fairly characteristic deformity in the pyelogram.

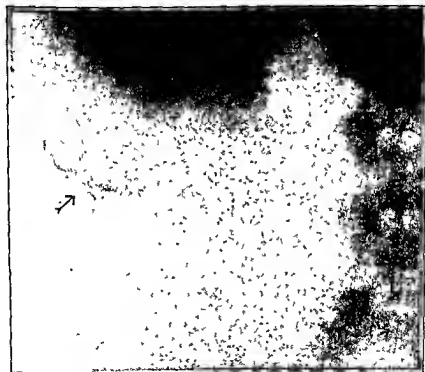


FIG. 236.—Roentgenogram showing deformity of the kidney pelvis due to a large hypernephroma.

Blood clots in the pelvis of the kidney may deform the shadow in such a way as to suggest a tumor. Pressure upon the kidney from enlarged adjacent organs, or extrinsic tumors, may prevent complete filling of the pelvis, and this appearance may simulate that of tumor. Spasm from instrumentation or injury to the ureter may duplicate organic defects but it does not persist and a repetition of the examination should reveal its true nature.

Adrenal tumors cause a flattening or deformity of the upper

calices if they are sufficiently large. Small tumors of the adrenal cannot be demonstrated on routine films but the Carelli method of injecting 200 cc. of air into the kidney bed brings the entire kidney and adrenal into striking relief and will visualize small masses which otherwise would be overlooked.

Neuroblastoma occurring in or about the adrenal in children causes characteristic lesions in the skull pelvis and long bones.



FIG. 237.—Polycystic kidneys.

Polycystic Kidney.—Cysts may simulate tumor in appearance, due to pressure upon the parenchyma. In polycystic disease, the calices are converted into long, finger-like processes which extend outward from the pelvis and the pelvis may be encroached upon to a certain extent. Usually the rounded impressions of the cysts can be seen overlying the calices and pelvis. The process is almost invariably bilateral.

Single cysts in the kidney substance may give no evidence of their presence when they are small. As they enlarge they produce a local rounded enlargement of the kidney shadow, with perhaps a slight compression of the adjacent calices. They may attain

considerable size without much deformity of the pelvis. They are best seen when they occur at the lower pole. When they occur within the pelvis, they cause round smooth defects (Fig. 238).

Chyluria.—In rare cases one finds in retrograde pyelograms, strands of opaque solution running toward the spine from the upper pole of the kidney due to lymphatic channels connecting the kidney and thoracic duct.



FIG. 238.—A cyst of the kidney pelvis. Note the rounded shadow of diminished density within the kidney pelvis.

THE URETERS.

The course and condition of the ureters can be demonstrated either by intravenous or retrograde pyelography.

Intravenous pyelography has the following advantages: (1) the ureter lies in its true course and does not conform to that of the rather rigid catheter, so that changes in diameter and irregularities of outline are clearly demonstrated; and (2) apparent kinking, due to pressure from the tip of the catheter, does not occur, whereas true kinks are easily recognized.

The course of the ureter is downward, across the transverse processes of the lumbar vertebrae and sacro-iliac joints to the pelvis.

It then curves inward and forward in the direction of the bladder. There are four points of narrowing where stones tend to lodge: (1) the uretero-pelvic junction; (2) where the ureter crosses the iliac vessels; (3) near the junction of the ureter with the bladder; and (4) the papilla within the bladder. Stones are found most commonly at the uretero-pelvic junction and just outside the bladder. They are easily overlooked if lodged near the iliac vessels, because their shadows are superimposed upon that of the sacrum. They may be projected free of the sacrum by a change in the position of the tube.



FIG. 239.—A calcified mesenteric gland suggesting a stone in the ureter.

Anatomical variations occur, the most common of which is multiple ureters. The ureter may arise from the posterior or lateral borders of the kidney. The lateral position is common in horse-shoe kidney. A posterior attachment is due to a congenital failure of rotation. Irregularities in outline are generally the result of infection. Tuberculosis is, perhaps, the most common cause, and first appears in the lower portion of the ureter which is stiffened and

straightened. Dilatation is generally due to obstruction within the lumen of the ureter, but may be the result of extrinsic pressure from pelvic tumors or adhesions. It occurs physiologically in pregnancy. Extreme dilatation sometimes occurs in advanced stages of carcinoma of the uterus, and occasionally in pelvic infections. Diverticula may occur in the lower portion of the ureter, and may contain stones.



FIG. 240.—Large calculus in dilated ureter. The dilated ureter is made visible by the injection of opaque solution.

The shadow of a *ureteral calculus* is oval or elongated, and somewhat hazy in outline and density. Its long axis lies in the direction of the course of the ureter. Shadows which may be confused with ureteral calculi (in addition to those already enumerated), are hypertrophic changes in the vertebrae and pelvic bones, arteriosclerosis of the pelvic arteries, calcified fibroids, calcified ovaries, dermoid cysts and phleboliths.

Phleboliths produce small, circular, sharply outlined shadows,

generally multiple, occurring in the pelvis in the region of the ischial tuberosities. They are the result of calcification in thrombi occurring on the distal side of the valves in the plexus of veins in the pelvic cellular tissue. They are common findings, and are frequently mistaken for ureteral calculi. The distinguishing characteristics of a calculus are: (1) it is not sharply outlined; (2) it is more likely to be oval than round; and (3) it lies in the course of the ureter above and internal to the area where phleboliths commonly lie. Furthermore, phleboliths seldom occur singly.

If there is any doubt in the mind of the examiner, the patient should be examined with an opaque catheter in the ureter, or an intravenous pyelogram made. Oblique films may then be obtained with the patient rotated so that the opposite hip is raised off the table. These will determine the presence or absence of obstruction, as well as the relation of the suspected shadow to the ureter.

Kinks in the ureters do occur and are usually due to aberrant vessels below the kidney pelvis. However, not every constriction in the ureter is due to kinking. Serial films show that there are definite peristaltic waves in the ureter and that apparent kinks seen on one film will disappear a few moments later. There is often an apparent kink in the ureter an inch or so below the pelvis when the patient takes a deep breath. The diagnosis of kinking should not be made when the ureter is deformed by the upper end of a rigid catheter.

Multiple small cysts throughout the ureter are seen in rare cases. They give a striking picture.

THE BLADDER.

The outline of the partially filled bladder can be made out occasionally in a pelvic roentgenogram. It can be readily visualized by filling it with air or opaque solution. Stones in the bladder are occasionally overlooked because a large percentage of them are urates. Important characteristics of bladder stones are: (1) they are of fairly large size; (2) they are oval, but sometimes laminated; and (3) they lie with their long axes transversely in the pelvis.

The bladder may be outlined by opaque solution, or by air. Large diverticula can be demonstrated, as a rule, after a moderate distention with opaque solution, or a partial inflation with air. Trabeculation of the bladder wall is sometimes visible, particularly along the sides. In some case it is possible to fill the ureter, and even the kidney pelvis, with opaque solution by slight overdisten-

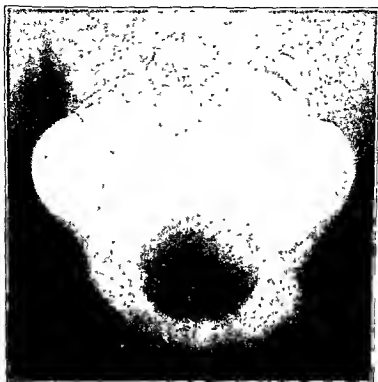


FIG. 241.—Roentgenogram showing a large calculus in the bladder.



FIG. 242.—Diverticulum of the bladder, demonstrated by opaque solution

tion of the bladder. This method may be used in cases when catheterization of the ureter is impossible, and is particularly adaptable to children.

Congenital abnormalities, such as hour-glass bladder and patent urachus, are sometimes found. The latter appears as a thin, dense line extending upward from the bladder toward the umbilicus.

Tumors may be sufficiently extensive to produce defects in the shadow of the opaque solution. The best method for their demonstration and one that is equally useful in the case of stone, is to inflate the bladder with air and obtain stereoscopic films. An enlargement of the prostate gland can be demonstrated by inflating both the bladder and the rectum with air. A deposit of calcium may occur upon the surface of bladder tumors, or it may appear within the tumor itself. In either case, the tumor can be demonstrated.

THE MALE GENITALS.

Small multiple calculi occur in the prostate, and may be mistaken for urinary concretions. The vas deferens and seminal vesicles, when injected with opaque solution, may appear distorted as a result of inflammation. Stones or foreign bodies in the urethra, if sufficiently dense, may be visualized.

The course and outline of the male urethra is well demonstrated by the injection of iodized oil or an opaque solution with the patient supine and rotated 45 degrees to one side. The bulbous anterior and contracted posterior portions are seen, and strictures, fistulae or diverticula become evident.

Carcinoma of the prostate is not recognizable but its metastases are characteristic. The metastases are usually of the osteoplastic type and are so heavily calcified that they produce a cottony or woolly appearance in the affected bones which are usually pelvis, spine and ribs.

THE FEMALE GENITALS.

Calcification is frequently seen in fibroids in the form of round, irregular dense masses, often multiple, and occupying any portion of the pelvis. In rare cases, the ovaries may be calcified. They appear as oval, flattened, spongy masses suggesting glands lying internal to, and above the ischium. They may be mistaken for ureteral calculi. With pneumoperitoneum, it is possible to outline the uterus, tubes and ovaries. Air may be injected into the

uterine cavity, in order to determine the patency of the Fallopian tubes.

The injection of lipiodol to outline the uterine cavity and determine patency of the tubes is simple and positive. The normal shadow of the body of the uterus is small and triangular with thin tortuous tubes leading away from the upper corners. If an excess of oil has been introduced, a few droplets will be seen below the tips of the tubes. Displacement or distortion of the body, its early enlargement in pregnancy, occlusion of tubes and their dilatation in chronic salpingitis are easily demonstrable.

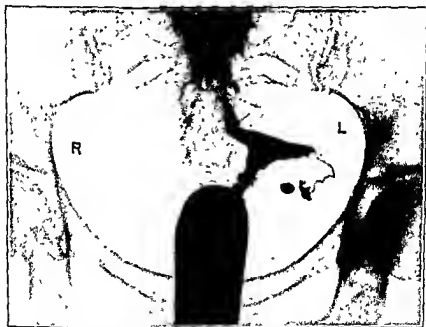


FIG. 243.—Injected uterus (lipiodol) showing occluded right tube.

Röntgenology is coming into increased use in pregnancy. The vague shadow of the fetus may be seen in favorable subjects as early as the twelfth week, and a definite diagnosis should always be possible by the eighteenth week. The patient should be examined in both prone and supine positions using the shortest possible exposure time to stop all motion of mother and child when searching for an early pregnancy. The size and position of the fetus is well shown. Multiple pregnancies are evident and the location of the placenta is often possible. In a small series of cases it

has been possible to diagnose intra-uterine death, from overlapping of the skull bones and shrinkage in size of the fetal head before it is engaged in the pelvis. Ancephalic monsters have been outlined. In one case of Siamese twins the heads lay close together on the same level, whereas the heads are reversed, one up and one down, or considerably separated in the usual twin pregnancy.

Clifford's tables of the relation between the occipito-frontal diameter of the infant's head and its weight are useful in determining the weight of the fetus in *utero*. The mortality under 5 pounds is 30 to 50 per cent, while between 5 and 6 pounds it is less than 3 per cent. For this reason the weight of the fetus may be of considerable help in deciding when a pregnancy may be safely interrupted.

A P diam of skull in cm	Minimum weight	Average weight
9 5-10	3 lbs.	3 lbs. 8 oz.
10 0-10 5	3 lbs.	4 lbs. 4 oz.
10 5-11 0	4 lbs.	5 lbs. 4 oz.
11 0-11 5	5 lbs.	6 lbs. 8 oz.
11 5-12 0	6 lbs.	7 lbs. 12 oz.

(With an anteroposterior diameter of 11, the transverse diameter is close to 9.5.)

These figures are taken from direct measurements and the diameters as recorded on the roentgen-ray films must be corrected for the magnification, due to the distance of the fetus from the film.

There are several methods of pelvimetry in use. One of the earliest in this country was suggested by Thoms and improved by Bowen. These rely upon measurements taken from a set of stereoscopic films. A simpler method suggested by Moloy requires a modification of the optical system of the ordinary stereoscope, so that a ruler may be held upon the combined image and direct measurements of the pelvis and skull read off at once.

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CHAPTER XI.

FLUOROSCOPIC TECHNIC.

It should not be forgotten that most of the injuries received by the early workers in roentgenology were due to the use of the fluoroscope. While the chief sources of danger in fluoroscopy have been removed, great possibilities for harm still remain.

Dangers to be guarded against are:

1. Electrical discharges from the high-tension circuit.
2. Roentgen-ray injuries to the patient.
3. Roentgen-ray injuries to the operator.

1. The hazard of contact with the high-tension circuit is largely concerned with the type of apparatus and the manner in which it is installed. In modern shock-proof apparatus this danger has been completely eliminated.

In other types of apparatus, and particularly in those operated from a separate transformer through an overhead system of wires, means should be provided making it impossible for any one to approach within striking distance of the wires. This is most easily accomplished by enclosing all high-tension conductors which may be located less than 7 feet from the floor with a barrier, which prevents access to the wires and allows at least a 6-inch air space between it and the leads.

Not more than one piece of apparatus should be connected to a transformer at the same time. All changes in the high-tension connections should preferably be made by overhead switches. Lacking these, a single pair of leads should arise from the transformer and be attached to whatever piece of apparatus is to be used, leaving everything else dead. Cord reels should always be kept in order and replaced at once if broken. Wires attached to overhead cord reels should not be permitted to hang lower than 7 feet from the floor, and higher if any metallic apparatus or material is likely to come within 6 inches of them at any time. This precaution is particularly important in fluoroscopic rooms, because in the dark one never knows where a dangling wire may be.

Small bedside and other self-rectifying units which are now in general use, are more dangerous than resistance-controlled outfits, and corresponding care should be taken to make sure that contact with the leads is impossible. Quick acting circuit breakers should be installed on all equipments which have no resistance in the primary circuit.

2. Danger to the patient from roentgen-rays will be minimized by using low milliamperage, by making all examinations as brief as possible, and by using the smallest possible diaphragm openings.

In the average fluoroscope with a 12-inch target skin distance, and 1 mm. of aluminum between the tube and patient, using 3 to 5 milliamperes, the exposure to the patient's skin is about 6 to 10 r. per minute. This means that a five minute examination, which is ample for any case, will result in the patient receiving less than $\frac{1}{16}$ of a skin dose. If films are made subsequently, this amount may be doubled or trebled.

3. Roentgen injury to the roentgenologist is due largely to lack of training and carelessness. One who is conservative and careful, never exposing himself to direct rays without an opaque covering and minimizing his exposure to secondary radiation, will not be conscious of any effects from the work after years of exposure.

On the other hand, those who insist upon wide-open diaphragms and the use of bare hands in palpation beneath the screen will surely regret their carelessness. It cannot be too strongly emphasized that permanent injuries do not usually appear until several years after the exposures responsible for them. It is well to acquire a conscience which will not permit an unnecessary moment of exposure.

The effects of over-exposure to radiation are, in the acute stage, itching, burning and erythema coming on from a few days to three weeks after exposure, and in the severe cases vesiculation and perhaps ulceration. The chronic effects which may appear without a definite erythema ever having been noticed are itching and tingling of the skin, numbness, brittleness of the finger nails, recession of the skin from the nails, blepharitis, telangiectasis, and atrophy of the skin; and in the later stages, keratosis and roughening of the skin which breaks down readily upon slight injury. These late effects usually appear in from three to ten years after exposure. It should not be forgotten that some of the earlier workers who used little or no protection died of aplastic anemia.

EQUIPMENT OF THE FLUOROSCOPIC ROOM.

The first essential in the fluoroscopic room is that it should be light tight when in use, for small cracks and leaks, in addition to detracting from the faint image on the screen, give rise to very troublesome reflections from its glass surface. The room should be sufficiently large to permit free passage about the apparatus, and should be well ventilated; the smaller the room, the greater the necessity for ventilation.

A small table or shelf should be provided to hold gloves, records and opaque meals. If the operator expects to spend much time in this room an extension telephone is useful. The room should be provided with an equipment for giving enemata.

Fluoroscope.—The tilting fluoroscope which permits vertical, horizontal and intermediate positions is an ideal arrangement. In gastro-intestinal examinations it is important to examine the patient both in upright and horizontal positions, and it is easier to complete the study on one piece of apparatus than to shift the patient, foot switch and high-tension current from one fluoroscope to another. A Bucky diaphragm beneath the fluoroscopic screen increases contrast and is of great help in the observation of fine details. Means should be provided for the taking of spot films with the patient in position on the fluoroscope. This requires a switch to change the settings on the transformer and means for shifting cassettes rapidly.

Filament Control.—The control for the filament current should be located conveniently close to the handles operating the shutters. A milliammeter in the high-tension circuit is essential, and should be so placed as to be easily read when the room is lighted, and, if possible, should be illuminated by a faint light visible at all times.

Lighting.—The room should be lighted by a fixture which contains one white and one red electric bulb. The red lamp should be connected with the foot switch which extinguishes it at the same time that the tube is lighted. The white light should be controlled by a separate switch, preferably in the wall.

Overhead Circuit.—Protection of the overhead circuit has already been considered. It should be substantially supported (not tied to the wall by strings), and to avoid corona, should consist of rods or tubing at least $\frac{1}{4}$ inch in diameter, with no sharp right angle turns and no sharp points. Spots which show corona should have large metallic masses placed about them. It should preferably be shock proof throughout.

PROTECTION.

Modern fluoroscopes are usually well protected, that is, so well lined with opaque material that no roentgen light is allowed to escape from the tube in any direction behind the shutters. However, it is an excellent idea to test the fluoroscope occasionally. This may easily be done by passing a loose fluoroscopic or intensifying screen all around the apparatus, at a distance of 2 or 3 feet, while it is in operation with shutter closed. There should be no light seen upon this test screen behind the plane of the surface upon which the patient rests. In the same way, a loose screen should be held in front of the lead glass on the instrument during examination of a patient, to determine its opacity. If an appreciable image comes through to the second screen, an extra sheet of lead glass should be added, or the faulty one returned to the manufacturer.

There is always a certain amount of radiation being given off in all directions from the patient during exposure—scattered and secondary rays. In order to properly appreciate their intensity, an extra screen should be held by the patient's side at different levels during the examination. One unaccustomed to it will be startled at the amount of radiation which proceeds from the patient when the diaphragms are wide open. Upon closing the shutters, this scattered radiation will be seen to progressively diminish until, by the time the luminous area on the screen in front of the patient has been reduced to a 2-inch square, it will have practically disappeared.

This striking demonstration of the variation in secondary radiation with the size of shutter openings, should cause one to acquire, in the beginning, the habit of working with the smallest possible illuminated area. A chair with a lead facing which covers the roentgenologist's chest and abdomen as he sits before the upright fluoroscope should be included in every fluoroscopic outfit.

Lead Gloves.—No matter how little fluoroscopy one does, he cannot afford to work without opaque gloves. He should no more think of doing fluoroscopic work without gloves than he would of handling caustics with unprotected hands. The fact that the roentgen irritant is unseen, and unfelt at the time, should make one all the more cautious in dealing with it.

Gloves can be kept in good condition by propping them open by wires and placing them in front of a fan when not in use, and dusting them with talcum powder before putting them on again.

A mitten constructed of a heavy grade of lead rubber, simply a

sack large enough to enclose the entire hand, with no partitions for thumb or fingers, is very comfortable. It airs itself well, affords complete protection to the hand and permits satisfactory palpation.

Wooden Spoon.—A very satisfactory palpating device consists of a flat board with a rounded tip outlined by a lead wire carrying a protective shield of lead into which the hand fits.

Lead Glasses.—Lead glasses are valuable for the prevention of marginal blepharitis, but are seldom necessary.

Lead Aprons.—Lead aprons are heavy and uncomfortable, but are essential and should always be worn. Unless they are heavy they are useless.

Accommodation.—One of the most neglected, but the most obvious preparation in fluoroscopy, is the acquisition of adequate accommodation requiring ten to twenty minutes in total darkness. In large clinics where several cases are being examined in succession, it is relatively easy to wait the necessary time at the beginning of the session. But, when it is necessary to examine a chest in the middle of a crowded afternoon, this preparation will always be slighted. One who is called upon for such examinations should do routine office work in a room that is as dimly lighted as possible. Direct sunshine should be particularly avoided. The wearing of tinted glasses will not interfere with ordinary work and it will be found that after having worn them, very satisfactory accommodation may be acquired in a few minutes in the dark room. The color is not particularly important, although reddish or orange tints give a slightly greater sensitivity to the greenish fluorescent screen.

Tests for adequate accommodation are:

1. The recognition of objects under the red light in dimly illuminated corners of the fluoroscopic room.
2. Visualization of the dial of a luminous watch in the dark.
3. The color of the fluorescent screen.

When accommodation is incomplete, it will be found that the screen shows a greenish hue in areas where the light strikes it without going through the patient. This color is replaced by a bluish-white light when dilatation of the pupil has occurred.

Secondary Current.—Under no condition, should more than 5 milliamperes be used on the fluoroscopic tube, and then, only for unusually heavy subjects. The ordinary current for routine work should not exceed 3 milliamperes.

Diaphragms are usually controlled from the side of the screen, and permit of any rectangular pattern.

In view of the great increase in secondary radiation when the shutters are wide open, the luminous area on the screen should always be kept as small as possible. It should not, under any circumstances, be permitted to approach closer than 1 inch to the margin of the screen. In the study of the stomach, a square, 4 inches in diameter, is ample. For the esophagus, a long vertical slit is best, and when watching the diaphragm, a narrow transverse band of light.

An additional advantage in the use of minimal areas is the brightening of the image which occurs—the narrower the beam of the roentgen-rays, the fewer scattered rays are produced to cloud and diminish the real image.

When the screen is moved away from the patient toward the operator, the image is magnified and becomes less intense, but the contrast is increased due to loss of the effects of secondary and scattered rays. This is often a useful maneuver in the observation of outlines which are somewhat indistinct in the routine examination. An adaptation of the Bucky principle is favored by many workers. It gives increased contrast and when properly adjusted the grids are not visible.

Rapidity of Work.—The beginner in fluoroscopy always works with too large shutter openings, and continues examinations an unnecessarily long time. He should constantly strive to keep his luminous area small and particularly to speed up his observations. A few seconds inspection will usually give all the information to be acquired from the screen. In the observation of continuous processes such as digestion, the light does not need to remain on during the complete examination. Short, repeated observations, with intervals during which slowly progressive movements may occur, or during which the patient may be palpated or changed in position, will give the same information as continued observation.

FRACTURES.

The fluoroscope is again coming into use for the observation of fractures, particularly in their manipulation previous to fixation.

In the primary diagnosis, the screen is not to be relied upon since well-defined breaks in bones may be overlooked if there is no displacement, or if the plane of fracture makes an angle with the central rays. However, once the presence and character of the injury has been established by films, the screen is of great help in determining

what maneuvers give the best position. Prolonged observations are not necessary.

If an anesthetic is used for the reduction, care should be taken that the room is well ventilated during the procedure; and if ether is used, that there is no possibility of sparks occurring in the room, particularly below the level of the table.

The use of apparatus not designed especially for fluoroscopic work increases the hazard both to the patient and to the operator. The shock-proof type of bedside apparatus is especially dangerous in untrained hands, as it permits a very close approach to the source of the roentgen rays.

FOREIGN BODIES.

It is important to realize that many foreign bodies do not show on the screen. Materials such as wood and glass may be missed even in thin masses of tissue such as a finger. Metallic objects will show if of sufficiently large size. Fine fragments, pins and needles are usually not visible if they are located in tissues more than 1 inch in thickness.

For the localization of foreign bodies, simple methods are the best. Four methods which proved satisfactory in military service will be described. In the first three, the patient should be placed in the same position in which he will lie on the operating table while the foreign body is being searched for.

The first and simplest method consists of exploring the patient systematically from head to foot with a fairly wide diaphragm opening, closing the shutters down upon suspicious shadows until the foreign body is located. Upon its identification, the luminous area is restricted to the smallest possible square above it, and a mark is placed upon the skin directly in line with the shadow of the object. The patient is then rotated as nearly as possible at right angles to the first position, and a similar mark placed upon whichever side is nearest the object. This gives the surgeon two landmarks at right angles to each other, from which to work.

The second, and perhaps the best, method for extremities is to proceed as in the first method and place the first mark. Then, beginning near the screen, intermittent pressure is made upon the skin lateral to the foreign body with an opaque tipped rod, gradually shifting the point of contact away from the screen until the foreign body shows its greatest excursion. A mark made at this point

where the movement of the foreign body most nearly corresponds to the movement of the palpating rod will be found to correspond surprisingly well with the second and lateral mark in the first method. It is also possible to estimate accurately by this procedure, the distance of the foreign body beneath the second mark.

The third method requires some adjustment of the tube and shutters, and is only useful when one expects to do a certain amount of foreign body work, and is willing to take the necessary trouble to prepare for it. The shutters controlling the lateral margins of the field are opened partially, and those which control the vertical extent of the luminous area are opened to the limit of their motion. This produces a vertical band of light upon the screen. The distance between the margins of the vertical shutters upon the tube box is now measured, and the position of the tube so adjusted that the target lies beneath the plane of the shutters a distance equal to the opening between them, and as nearly as possible midway between them. The screen must be detached from the tube and remain stationary upon the patient. The use of this method is extremely simple. First, the position of the foreign body is centered and marked upon the skin as in the other methods; the vertical shutters are opened to their widest extent, and the lateral shutters adjusted to give a vertical band of light 1 or 2 inches wide. The tube is shifted along the vertical axis of the patient until the extreme end of the lighted area bisects the foreign body. The position of its image is marked upon the screen at this point. Without disturbing the screen or the patient, the tube is shifted in the opposite direction until the tip of the luminous oblong again bisects the foreign body. A mark is placed at this point on the screen. The distance between these two marks is the depth of the foreign body beneath the screen. If the screen lies in direct contact with the skin, it will be the distance beneath the skin. Otherwise, a correction must be made for the screen-skin distance.

So far, one skin point and the depth beneath it have been recorded. It is a simple matter to rotate the patient to any desired position and repeat the process and, so secure several skin marks with their corresponding depths. This method is particularly useful for the localization of opaque objects in the skull and trunk.

The fourth, by far the most satisfactory procedure, is the operative removal of foreign bodies under fluoroscopic control. The operation is done upon the horizontal fluoroscope. A white light enables the

necessary preliminary arrangements to be made, after which it is turned out, and the remainder of the work done under the red fluoroscopic light assisted, perhaps, by a small electric lamp attached to the surgeon's head, or carried by a nurse. After the incision has been made in the most favorable position near the foreign body, a clamp or pair of forceps is introduced and manipulated under the fluoroscope until it is seen to be in proximity to the shadow of the foreign body. The tip of the clamp is then moved slightly from side to side. If the shadow moves with it, the clamp is then close to the position of the foreign body and should be attached to the tissues at this point. Careful dissection in this region will usually bring one shortly to the desired object, although small foreign bodies may be so surrounded by soft tissue as to be unrecognizable when they are actually in the grip of the instrument.

If the shadow does not move with the clamp, the tip of the latter should be raised to the surface of the wound, then gradually depressed, at the same time being moved from side to side until the lateral movement of the shadow of the body corresponds to that of the instrument. Rotation of the patient to the side may be of assistance. It may be necessary to deepen the incision in order to allow the instrument to come in contact with the foreign body. A variant of this procedure, useful in small foreign bodies in the hand, is to introduce two needles at right angles to each other, which are made to touch the body under fluoroscopic observation. Then under ordinary light the surgeon works down to their intersection.

Skin Marks.—Skin marks are best made with wax pencils or ink, and after the white light is turned on, a stick of silver nitrate should retrace the marks. If a drop of developer is then placed upon the spot, the mark will become relatively permanent.

In localization where the skin is loose, skin marks, of course, may shift considerable distances from their normal relation to the foreign body, and once an incision has been made, the surgeon loses track of his landmark to a large extent; so that all skin marks are, at the best, approximate guides only.

CHEST.

Examination of the chest is best conducted with the patient upright on the fluoroscope. It may occasionally be necessary to view an individual in the prone or supine position where pericardial or pleural effusion is present, or when he is too weak to stand. One

advantage of the tilting screen is the ability to place a sick patient upon it horizontally and slowly elevate the head until he is practically in the erect position.

All clothing above the waist should be removed. The patient should face the operator, and should breathe in and out slowly and quietly.

The examination is preferably conducted in a routine manner. One soon falls into the habit of looking at the patient in a definite sequence and the possibility of overlooking some detail is avoided.

A general survey of the entire chest is made with a fairly wide diaphragm, care being taken to look for calcified masses in the neck (glands or thyroid), contraction or clouding of the apices, areas of increased or decreased density in the lung, movement of the diaphragm, and general size of the heart and aorta.

The shutters are now partially closed, and the apices examined one at a time and compared for radiability, expansion, and (most important of all) expansion and lighting up upon cough. To properly bring this out, the patient's head is rotated over one shoulder, (the left for example) in order to draw the sternocleidomastoid clear of the right apex. He is instructed to cough vigorously and the right apex is carefully watched. If it is normal, it will be seen to expand slightly but definitely, and to become momentarily brighter than before. The same observation should be repeated upon the left apex, with the head over the right shoulder and the resulting expansion compared with that of the right. This expansion and increased radiability of an apex upon cough is a valuable bit of evidence, as failure to expand is due either to active lung disease or thickened pleura. Normally the left apex expands somewhat less than the right.

The remainder of the lung fields, particularly the region of the interlobar septa, should next be carefully studied, and the two sides compared.

The movement of the diaphragm may now be investigated. It should move equally on the two sides, and there should be no lag of one half behind the other, either wholly or in part. Movability of the diaphragm is best brought out by normal respiration, as the exaggerated movements of deep breathing may mask slight inequalities.

Next, the costo-phrenic angle on both sides should be observed to determine whether or not the diaphragm peels away freely from the parietal pleura under the descending edge of the lung, or whether

the angle is obliterated by fluid or adhesions. Deep respiration should be employed for this purpose.

The central shadow should now be gone over from below upward, looking first at the heart, with an opening just large enough to include the entire organ. One should observe the size, shape, amplitude, regularity, and, as far as possible, sequence of pulsation in the different chambers.

The ascending, descending and transverse portions of the aorta are next investigated, noting size, position, and amplitude of pulsation.

Finally, the superior mediastinum is covered to rule out shadows which might be due to thyroid, thymus, dilated bloodvessels, or a new growth.

The patient should now be rotated about 60 degrees to the left, bringing the right shoulder forward against the screen, and note made of the diameter of the ascending and transverse portions of the aorta. The patient is requested to take a deep breath, and the posterior mediastinum, the thickness and position of the heart, the condition of the bases of both lungs and the costo-phrenic angles observed. The patient may now be rotated in the opposite direction with the left shoulder forward and the heart, aorta and bases of both lungs gone over. Finally, he should be turned with his back to the examiner and another survey made of the apices, both before and after cough, of the lung fields and the costo-phrenic angles. Observation of the patient turned at right angles to the examiner is often useful.

The description takes as long as the actual observation. If one will accustom himself to such a routine, the whole examination can be completed in a few minutes and nothing will have been overlooked.

In the study of cardiac cases, it may be found valuable to incline the patient to the right and to the left, to demonstrate displacement of the heart and to observe its movement upon deep inspiration in the transverse position. Tracings also may be made to show its outline and position with reference to the chest wall and the diaphragm during inspiration and expiration. Such tracings are best made upon a screen which is fixed with reference to the patient and does not move with the tube. Patient and screen must remain stationary during the examination. The shutters are closed down to project a small illuminated area which is carried along the outlines

to be recorded. Dots are made upon the glass with a skin pencil at suitable intervals along this outline. These outlines can later be transferred to thin paper after the patient has been dismissed.

GASTRO-INTESTINAL EXAMINATION.

Either single or double meals may be employed. The double meal saves one visit and is the method usually employed in large clinics. Using this technic, the patient takes along with his ordinary breakfast, 1 ounce of barium sulphate stirred in water or milk. This drug should always be specified as "C.P. for roentgen-ray use, to be taken internally," when ordered on prescription; and better, dispensed to the patient directly from the physician's office in order to avoid the unfortunate and even fatal accidents which may arise from the use of soluble barium salts.

The patient should report for observation six hours after breakfast, having taken no food in the meantime. He is placed in the standing position, a brief survey of the heart and lungs is made, abdomen searched for possible residue in the stomach and the position of the six-hour meal. A mouthful of a sticky barium suspension is administered, and the examiner notes the manner in which the liquid outlines the esophagus and enters the stomach. Another swallow will be sufficient to outline the mucosal pattern in the stomach, which is carefully studied under palpation for deformities or ulcer niches. A portion of the mixture may be pressed through the pylorus to outline the first portion of the duodenum. Spot films may be taken of any interesting areas. Then the stomach is filled with 6 to 8 ounces of the standard barium meal and a careful search is made with a small diaphragm opening for defects in outline in both anteroposterior and three-quarter oblique positions. The patient is then placed horizontally upon his back, the cardiac end of the stomach carefully gone over, and the ileum, cecum and appendix palpated to determine their mobility, separability, and the location of any tender points. The patient is next turned face downward and the region of the esophagus investigated for evidence of regurgitation through the cardia.

The outline of the stomach is carefully examined for defects, and the progress and character of the peristaltic waves studied on both curvatures. If the pyloric region and duodenum are well outlined, their behavior is observed. Often it will be necessary to elevate the patient's left side so as to rotate the stomach clear of the duo-

denum which will then lie between the stomach and vertebræ. The anterior and posterior margins of the gastric shadow are easily observed in this position, and the pylorus and duodenum are well seen in profile.

The examination should be continued until the examiner is satisfied as to whether or not there are defects in gastric or duodenal outline or peristalsis. The relation of any unusual masses of opaque material to the stomach and duodenum should be determined by rotating the patient, or by further observations. Thoroughness is essential. If there is the least doubt in the examiner's mind regarding the findings, the examination should be repeated. Films should always be secured, if possible, to check the screen findings and for a permanent record.

In cases of suspected ileocecal disease, a nine-hour observation should be made. This can be accomplished by postponing the observation of the stomach until the nine-hour interval has elapsed, or by a nine-hour meal given on a subsequent date. The patient should be allowed to eat his usual meals during the nine-hour period. The questions to be determined at this examination are presence of a residue in the ileum, visibility of the appendix, mobility of cecum and appendix, and location of tender points.

The next observation should be twenty-four hours after the first. This often gives valuable information corroborative of that obtained at the first observation and should not be omitted. The position of the meal, and the mobility, position and tone of the colon are investigated.

To complete the examination, an enema should be given for which the patient should be prepared by a thorough emptying of the colon. The same barium malted milk mixture used for the meal is employed, slightly warmed. The tube is inserted with the patient lying on his side. He is turned on his face and the enema allowed to flow in from a vessel two to three feet above him. The progress of the fluid is carefully watched, and when it reaches the tip of the cecum, the tube may be removed. The positions of the pelvic loop at the beginning, and after complete distention, are noted. Overlapping shadows and loops are separated as well as possible by rotating the patient to one side or the other, or by palpation. Defects, dilatation and diverticula are searched for, and the competence of the ileocecal valve noted. Occasionally, the appendix will fill by enema when it has failed to show with the meal. It should always be looked for when the cecum

is palpated. Reexamination after evacuation of the enema may help to corroborate previous findings, and should be done as a routine. In some cases inflation with air after evacuation of the barium will prove helpful. No roentgen examination of the gastro-intestinal tract should be considered complete until an observation is made immediately, six hours, and twenty-four hours after taking the barium meal; and until a barium enema has been given. Several films should be taken to check the fluoroscopic findings and for purposes of record. Anything less is unfair to the patient, to the physician, and to roentgenology. The more one sees of this work, the more he will realize that accurate results can only be obtained by painstaking observations, repeated several times if necessary. The accuracy of the method will vary directly with the care and time spent upon it.

In conclusion, it must be pointed out that the possession of a fluoroscope does not make a roentgenologist. Careful preparation for this work is as essential as it is in any laboratory branch of medicine. It is a field of its own which cannot be mastered in a few weeks. Sustained enthusiasm, experience and careful work are the essentials of success.

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